

Radiation Protection In Chiropractic Radiography

Guidance notes on the
Ionising Radiations
Regulations

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**British
Chiropractic
Association**

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Preface to the second edition

The adoption of digital x-ray imaging technologies throughout the chiropractic profession has been impressively rapid and widespread. Other imaging modalities have matured and become accessible since the first edition was published in 2000, and a number of relevant official clarifications and legislative amendments have been promulgated. It was therefore considered opportune to completely review and update the text, with a wider scope.

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Preface to the first edition

Radiology and modern chiropractic were founded in the same year (1895), the one on Röntgen's chance discovery and brilliant investigation of x-rays, and the other on Palmer's inspired scientific analysis and development of the traditional healing art of manipulation. Radiological evaluation has been integral to the chiropractic armamentarium ever since.

A century on, the founding of the General Chiropractic Council almost simultaneously with the embodiment of European Council Directives on radiological protection into British law, provided the impetus for compiling these Guidance Notes. They are intended to draw attention to the aspects of the Ionising Radiations Regulations that apply particularly to the use of x-rays by chiropractors, to set out effective means of complying with the Regulations, and to summarise good professional practice in chiropractic radiography.

This is not a manual of radiodiagnosis, nor is it intended to teach the underlying principles of x-ray imaging or radiation protection: these are matters for the undergraduate syllabus and post-qualification seminars. It is intended to be read alongside the Regulations as a practical guide to setting up and operating an x-ray facility in a chiropractic clinic, or referring patients to off-site x-ray facilities.

Parliamentary statutes alone do not define the law in Great Britain. Much is intentionally left to the precedents and interpretations established by the Courts. Guidance Notes thus fall between two stools: if published at the same time as the Regulations they may be useful but ultimately inaccurate, but if they are delayed pending judicial clarification of all the Regulations they will be of academic interest rather than practical value to the majority of their readers.

As the X-ray Standards Committee of the British Chiropractic Association is committed to reviewing and updating its guidance to members, it was considered preferable to err on the side of early publication.

These Notes refer to the Ionising Radiations Regulations 1999 (IRR), which came into force on 1 January 2000, and the Ionising Radiations (Medical Exposure) Regulations (IRMER), which took effect on 13 May 2000. They are written as a compilation of professional opinion and in good faith, but no liability is assumed for their accuracy or completeness.

July 2000

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1.1 Definitions

IRR 2 Dose is the physical quantity of energy absorbed per unit mass from a source of ionising radiation. It is expressed in grays (Gy) or more commonly in radiology, milligrays (mGy).

Equivalent dose is a derived quantity that accounts for the relative effect of different types of ionising radiation on biological *tissue*. It is expressed in sieverts (Sv). Since x-rays are the reference radiation, for chiropractic purposes equivalent dose is numerically equal to physical dose.

Effective dose is the summation of equivalent doses over the whole body, weighted for the radiosensitivity of each irradiated *organ*. Effective dose is therefore related to the risk of actual harm arising from the exposure of a human subject to ionising radiation. It is expressed in Sv. Organ weighting factors *W* as recommended by the International Commission on Radiological Protection (2007) are

Lung	0.12
Stomach	0.12
Colon	0.12
Bone marrow	0.12
Breast	0.12
Gonads	0.08
Thyroid	0.04
Oesophagus	0.04
Bladder	0.04
Liver	0.04
Bone surface	0.01
Skin	0.01
Brain	0.01
Salivary glands	0.01
Remainder	0.12

Health and Safety Executive is the statutory body responsible for enforcing the Ionising Radiations Regulations 1999 (IRR99). In Northern Ireland this duty is assigned to the Department of Economic Development, but the abbreviation HSE is used throughout these Notes. The Ionising Radiations (Medical Exposure) Regulations 2000 and 2006 (IRMER) are enforced by the *Care Quality Commission* (CQC) or territorial equivalent.

"*Liable*" and "*likely*" are used in the Regulations. These are unusual terms in law and may need judicial interpretation. It appears defensible to interpret them as "contractually liable" - i.e. within the agreed scope of employment, and "more likely than not".

Quality is used throughout these notes to denote "conformance with requirements". *Quality assurance* is the systematic anticipation and prevention of non-conformance ("test before use" - e.g. "check the fuel gauge before setting off"). *Quality control* is the in-process or retrospective resolution of non-conformance ("check and rework" - e.g. "read the map en route").

Radiation employer, usually the practice principal, is the employer who in the course of business carries out work with ionising radiation. The term "employer" is loosely applied in the Regulations and effectively means the person in overall charge of a particular location, *whether the operators, etc., are contracted as employees or occupy the premises as tenants*. The term is used quite differently than in general employment law.

1.2 Outline of statutes

1.2.1 General principles of radiation protection

The use of x-rays in chiropractic will result in
 intentional irradiation - of a patient
 contingent irradiation - of an operator
 adventitious irradiation - of third parties

Since exposure to ionising radiation is always harmful to living tissue, the overriding principles adopted by the International Commission on Radiological Protection (ICRP) are that any controllable exposure of persons must be justified - so that the prospective net health or economic gain outweighs the harm done
 optimised - to yield the maximum benefit from the amount of radiation used "as low as reasonably achievable (ALARA)" - using as little radiation as possible, taking account of the circumstances. In British law, ALARA is replaced by ALARP - "as low as reasonably practicable" subject, in the case of contingent and adventitious irradiation, to dose limits

1.2.2 The Euratom Directives

Directive 96/29/EURATOM requires Member States of the European Community to protect the health of workers and the general public against the dangers arising from ionising radiation. It lays down dose limits for radiation workers and the general public.

Directive 97/43/EURATOM addresses the protection of patients from medical use of ionising radiation. Among other things it lays down requirements for justification, optimisation, quality assurance, and recordkeeping, and deals with "medico legal" exposures.

1.2.3 UK Statutes

The Ionising Radiations Regulations 1999 (IRR) embody most of the requirements of Directive 96/29 in a framework of English law, and set out the minor variants applicable to Scotland, Wales and Northern Ireland. They form part of the Health and Safety at Work Acts, and place duties on any employer in regard to the protection of employees and third parties (the general public, "comforters and carers" and "outside workers" - i.e. contractors). They also include some provisions relating to the design and construction of medical radiation facilities that derive from the Medical Exposures Directive. Enforcement of IRR is the responsibility of the Health and Safety Executive (HSE).

The Ionising Radiation (Medical Exposure) Regulations 2000 (IRMER) embody the remainder of the Medical Exposures Directive. They set out the duties of employers, "referrers", "practitioners" and "operators" with regard to the radiation protection of patients and of volunteers in clinical research. Enforcement of IRMER is the responsibility of the Care Quality Commission (CQC). They have been amended by the Ionising Radiation (Medical Exposure) (Amendment) Regulations 2006 which introduced a number of new definitions, most significantly restricting the privileges and duties of a referrer to members of "regulated professions" regardless of the impact that might have on the patient's health.

Copies of the Regulations are obtainable from The Stationery Office or by download from

www.opsi.gov.uk/si/si1999/19993232.htm (IRR99),

www.opsi.gov.uk/si/si2000/20001059.htm (IR(ME)R2000)

www.opsi.gov.uk/si/si2006/20062523.htm (IR(ME)R Amendment 2006)

2.1 Notification to HSE

IRR 6 The radiation employer must notify HSE at least 28 days before first using x-ray equipment at any premises, and in the case of any "material change". The Radiation Protection Adviser (RPA - see 2.4) will advise on the definition of material changes - they are unlikely to occur in chiropractic clinics. A pro-forma for initial notification is appended to these Notes at 7.2, or notification can be made on-line via

www.hse.gov.uk/radiation/ionising/notification.htm

2.2 Restriction of exposure

IRR 7 Every new installation must be designed in consultation with an RPA. The design must incorporate a risk assessment and the radiation employer must have documentation showing how the installation has been designed to

- prevent accidental irradiation
- optimise patient dose
- restrict the dose to any other person to less than 1 mSv/yr

taking into account the probable work load and exposure factors that will be used.

Experience has shown that it is entirely practicable to apply the "public" dose limit (1 mSv/yr) to all employees in chiropractic clinics, whether they operate the x-ray equipment or not.

IRR 8 Primary design (of walls, doors, and equipment layout) should make accidental irradiation most unlikely and secondary prevention (an indicating door bolt that can be overridden in an emergency) is more effective than tertiary warnings (a notice outside a door) in preventing unauthorised entry.

It is rarely necessary to use interlocks, warning lights or notices to prevent accidental irradiation in a chiropractic clinic: these measures should be regarded as means of last resort, and experience shows that warning lights outside an x-ray room have no effect on staff behaviour. If used, an interlock must not interrupt an exposure that has already commenced, and must be sufficiently reliable not to interfere with normal use of the equipment. HSE requires interlocks that cannot be overridden.

Disposition of the x-ray equipment to make best use of the radiation protection properties of existing structures must be weighed against immediate ergonomic factors and the probable future use of the x-ray room and surrounding areas. The practical experience of the x-ray supplier and the RPA are particularly valuable in this respect.

If it is not reasonably practicable to protect an area that could occasionally be occupied during an exposure, say outside a window, the risk analysis must show how accidental irradiation will be avoided by local rules and operator vigilance.

2.3 Radiation Protection Supervisor (RPS)

IRR 17 If the employer has designated a controlled or supervised area, a suitable person (the RPS) must be appointed by the radiation employer to implement the Regulations and require compliance with the local rules in that location. In practice it is convenient to nominate an RPS for every clinical x-ray facility. The RPS is usually the principal chiropractor but may be the local senior associate in one of a group of practices, or a qualified radiographer. The RPS must be named in the local rules.

2.4 Radiation protection adviser (RPA)

IRR 13 A certified and suitably experienced person must be appointed by the radiation employer to advise on matters as required by the Ionising Radiations Regulations. The appointment must be in writing. The RPA is rarely an employee and need not be local to the practice.

The "matters" set out in Schedule 5 of IRR are, in the case of chiropractic,

- The implementation of controlled and supervised areas
- Prior examination of plans for, and acceptance testing of, new or modified x-ray equipment and facilities, and
- Periodic examination of safety features.

The British Chiropractic Association can recommend suitable RPAs with relevant experience. The certificating organisation RPA2000 (www.srp-uk.org/rpa2000) maintains on-line lists of currently certified RPAs but does not specify their areas of expertise.

2.5 Medical physics expert (MPE)

IRMER 9 The employer must ensure that a medical physics expert (MPE) is available for consultation on optimisation, patient dosimetry and quality assurance, and to give advice on radiation protection. The RPA is usually able to fulfil this role, or should be able to recommend a suitable person. The expert need not be an employee, or even local to the site. **IRMER 2** states "medical physics expert" means a person who holds a science degree or its equivalent and who is experienced in the application of physics to the diagnostic and therapeutic uses of ionising radiation.

There is at present no single qualification but a State-registered Clinical Physicist with diagnostic x-ray experience would in general be suitable. The Health Professions Council www.hpc-uk.org carries lists of registered clinical scientists but does not detail their areas of expertise.

2.6 Referrer, practitioner and operator

IRMER 5 The Regulations assign duties to three notional persons involved in requesting, authorising and carrying out a medical radiation exposure. The "referrer", who must be a health care professional registered with one of a number of designated bodies but need not be an expert in radiology, must supply sufficient information to the "practitioner" (also a registered healthcare professional) to allow the latter to evaluate the prospective benefit and decide whether to authorise the exposure. The exposure is effected by the "operator" who must optimise the exposure by good professional practise.

In most chiropractic clinics, a single chiropractor will assume all three roles, but proper records must be kept to show that each assigned duty has in fact been carried out by a person duly trained, qualified and aware of his status at the time. A model record system is given in 7.3

Evaluation of the exposure (in effect, reading and reporting the image) is an "operator" function, even though in most cases it is done by the "practitioner". Matters are further complicated by the presence in hospital settings of nurse practitioners (who may or may not be authorised referrers but are probably not IRMER practitioners), radiographers (who may describe themselves as radiographic practitioners, especially if they have reporting credentials, but are in fact operators) and medical practitioners (surgeons and physicians) who request "unreported" images and thus assume the roles of referrer and operator but not that of practitioner.

2.7 Designation of areas

IRR 16 The employer, in consultation with an RPA, must designate controlled or supervised areas where

- it is necessary to implement special procedures to restrict exposure or
- an employee is likely to receive a significant exposure or
- it is necessary to keep the area under review regarding potential radiation exposure or
- any person (except a patient) is likely to receive an effective dose exceeding 1 mSv in a year.

These conditions do not normally apply in a well-designed chiropractic clinic: the complications associated with them can be avoided by careful design and conscientious use of the clinic.

The potential risk of exposure is significant where fluoroscopy is used, and in these instances a temporary controlled area may be needed.

IRR 18 Where a controlled or supervised area has been designated, there must be effective means of restricting access to a controlled area or warning of the risks associated with a supervised area. The RPA must be consulted.

2.8 Local rules

IRR 17 The purpose of local rules is to set out any variants or restrictions on normal professional practice that are required in order for work to proceed in accordance with the Regulations. They must be drawn up in consultation with an RPA and must be brought (by the radiation employer) to the attention of anyone who may be affected by them.

Local rules are mandatory where the employer has designated a controlled or supervised area, and are advisable in all clinics. It should not be necessary for local rules in chiropractic practices to extend to more than two pages of typescript.

The RPS is responsible for ensuring that work is carried out in compliance with the local rules.

The essential contents of local rules are

- (a) the dose investigation level - see below
- (b) contingency arrangements
- (c) the name of the RPS
- (d) identification of the area to which the rules apply, including whether and when a controlled or supervised area exists
- (e) a summary of working instructions affecting radiation safety

A model set of local rules is appended at 7.3

IRR8 (7) requires an employer to carry out a formal investigation if any employee receives a dose in excess of the employer's specified investigation level, which may not exceed 15 mSv in a year. This is 75% of the annual dose limit for an employee. In chiropractic practice it should not be necessary to specify an investigation level exceeding 75% of the dose limit for a member of the public, i.e. 0.75 mSv/yr. The prior risk analysis of a properly-designed chiropractic x-ray facility (which must be made in consultation with an RPA) should show that this cannot be exceeded other than intentionally or by direct accidental exposure to the primary beam, so there is no requirement to monitor personal dose, but any unintentional exposure of a member of staff to the primary beam will initiate an investigation.

The RPS should contact the RPA with as much detail of the incident as possible, in order to decide whether the incident is notifiable to HSE or any other authority. In an intentional exposure to the primary beam, the employee will have the status of a patient, to whom no dose limits apply. Intentional exposure to scattered radiation outside the operator's protected area is a disciplinary offence as it contravenes the local rules.

2.9 Medical exposures - general requirements

IRR 32 Equipment must be designed, constructed, installed and maintained so as to restrict patient exposure "to the extent that this is compatible with the intended clinical purpose...." There must be means of informing the operator of the quantity of radiation produced, and there must be a suitable quality assurance programme to ensure that exposure remains adequately restricted.

Medical x-ray equipment must be tested before it is first used and at suitable intervals thereafter. "Testing" is generally held to imply an assessment independent of the maintenance engineer's status checks or the clinic's routine quality assurance procedures.

IRMER 5,6,7 requires that every medical exposure is justified and optimised, and that the employer has adequate measures in place to limit and assess patient exposure to ionising radiation. Certain records must be kept for each patient who undergoes a radiological examination - see 4.4

IRMER 8 The employer must institute procedures for "clinical audit", a systematic review of radiological practices and outcomes. Suitable instructions are given in the Model QA System, 7.6.

2.10 Training

IRMER 11 The employer must ensure that all practitioners and operators are adequately trained, and must maintain a separate training record of current and past employees.

IRMER 4 The employer must ensure that every practitioner or operator undertakes continuing education and training after qualification.

IRMER 11 (1) The relevant parts of the Schedule setting out the theoretical knowledge and practical experience requirements for practitioners and operators are appended to these Notes at 7.11

2.11 Dose assessment and monitoring

IRR 19 Proper design of a chiropractic x-ray facility should ensure that doses to staff and third parties arising from radiography are below the limits of practical measurement, so that neither staff nor area monitoring is needed. It is however essential that the radiation employer consults the RPA regarding any proposed change of use or layout, to ensure that the design requirements remain satisfied.

IRMER 4 The employer must institute and maintain procedures for assessing patient dose. In practice, it is sufficient to record the technique factors (kV, mAs, ffd) for each radiographic exposure.

The medical physics expert will provide guidance on estimating entrance skin dose, and will be able to estimate organ and foetal doses, from this data. Section 4.3 provides a means of estimating entrance skin dose from the calibration data for a given x-ray installation.

2.12 Incidents and contingency plans

IRR 12 If the x-ray facility has been properly designed, and the x-ray generator is a conventional rotating-anode system, the only reasonably foreseeable radiation accident is the failure of the generator timer to terminate an exposure. The local rules must set out the contingency plan (usually, "switch off, isolate, evacuate") and the radiation employer must ensure that all operators are able to carry it out.

IRR 25, IRR 32 (4) and IRMER 4 (5) The employer must investigate any actual or suspected incident in which a person was exposed in excess of a dose limit, or to an extent "much greater than intended" as a result of a fault or malfunction of the x-ray equipment. The RPA will advise and his expertise will in any case be needed to carry out and report the investigation.

Dose variations of $\pm 10\%$ are within the specification limits of most x-ray equipment, and variations of less than $\pm 20\%$ do not generally affect the clinical value of spinal radiographs. Recurrent "unusably dark" films (3 x overexposure) or a single "totally black" film (10 x overexposure) may be caused by a notifiable malfunction: the RPA must be consulted as soon as possible. A clear "failure to terminate" an exposure must be investigated immediately - the equipment must be taken out of service until the investigation is complete and a repair has been certified satisfactory.

Occasional operator error, or a dubious clinical decision that leads to an unusable radiograph, does not constitute a notifiable incident. However it is essential to record all such occurrences and to review the exposure log book to ensure that diagnostic reference levels are not "normally" exceeded, accidentally or intentionally.

2.13 Purchase and sale of x-ray equipment

IRR 31 The supplier of x-ray equipment must provide the radiation employer with adequate instructions for use, testing and maintenance of the equipment and must ensure that a critical examination of the finished installation is carried out (in practice usually by the purchaser's RPA) before the equipment is used.

"Supply" is normally interpreted as "supply by an acknowledged trader". Used equipment sold "as seen", either as surplus for disposal or as part of a working clinic, does not carry a trader's liability, though there is a general duty of care to hand over all relevant documentation and maintenance contracts. However if an owner offers to reinstall his surplus equipment in another person's clinic he is acting as a trader, even if the reinstallation work (or the equipment itself) is a gift.

IRR 32 The employer must ensure that the equipment is subject to an acceptance test before its first clinical use. In practice this will be an extension of the critical examination.

IRMER 10 The employer must maintain an up-to-date inventory of the radiation equipment at each installation. This should be checked as part of the acceptance test and updated whenever equipment requiring an acceptance test is acquired or modified. The inventory must not exceed the quantity of equipment actually required for the work carried out at the installation.

3. Premises and equipment

3.1 Structure and design of x-ray rooms

3.1.1 Practicalities

Scattered radiation can be considered as emanating from an area about one-third of the depth into the patient. Polar diagrams have been published showing the distribution and intensity of scattered radiation from common beam geometries and kV values. The "inverse square law" cannot be applied closer than 1 m from the patient and special attention must be given to the design of radiation barriers close to the bucky.

The attenuative properties of common building materials, including lead sheet and barytes "x-ray" plaster, have been published. The attenuation of prefabricated sections (such as plasterboard or honeycomb concrete floors) can be calculated by the RPA. The spectrum of scattered radiation from diagnostic x-rays is sufficiently similar to the primary beam that it is usually simplest to design each radiation barrier as if it were intercepting a fraction of the primary beam dose rate, at the primary beam energy.

"Leakage" radiation from the x-ray tube and collimator should be negligible at the kV values used for chiropractic radiography, but good practice requires that no part of the operator can "see" the tube or the patient directly from the normal operating position. There is then no possibility of the operator receiving first-scatter radiation from objects such as filters and blockers in the primary beam.

The workload of the average chiropractic x-ray unit is low enough that secondary scatter (from walls and ceilings) is unlikely to be a significant contributor to personal doses. However the RPA must be aware of its potential importance and operators must always consider the possibility of secondary scatter fogging an exposed film if it is not properly shielded during a subsequent exposure.

3.1.2 Organisation and inspection

IRR7 A 3-stage process is usually sufficient to design and document a new chiropractic x-ray installation

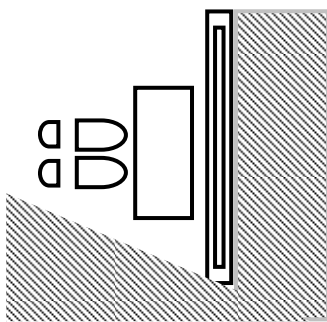
- (1) chiropractor makes a preliminary sketch or (preferably) obtains an architect's drawing of the clinic, showing the intended occupancy outside the x-ray room, and structural materials.
- (2) x-ray supplier prepares a detailed layout proposal for RPA and chiropractor. This will include essential preparatory works such as plumbing and providing electrical outlets.
- (3) RPA prepares risk analysis and local rules, and specifies any additional protective materials or devices

The employer must submit his pro-forma notification to HSE in good time, and act on any additional requirements that HSE may impose.

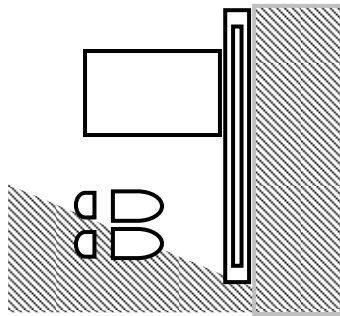
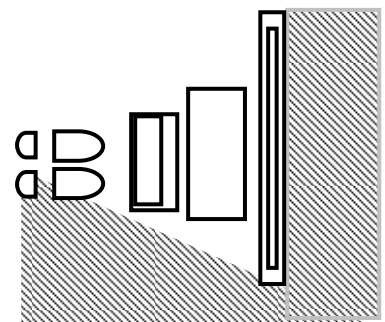
The supplier must contact the RPA as the installation progresses, arrange a suitable time for the critical examination, and act on the findings of that examination and the acceptance test

3.1.3 Designing for continued safety in x-ray rooms

A chiropractic x-ray room will usually include a lead ply/lead glass panel "upstream" of the control desk, to protect the operator. It is essential that the operator stands in the intended position so that scattered radiation is intercepted by the protective panel. If the control desk is moved, or clutter such as loaded cassettes is allowed to accumulate around the control desk, the operator may be forced to stand in an area of significant scattered radiation. The diagrammatic plans show two common problems

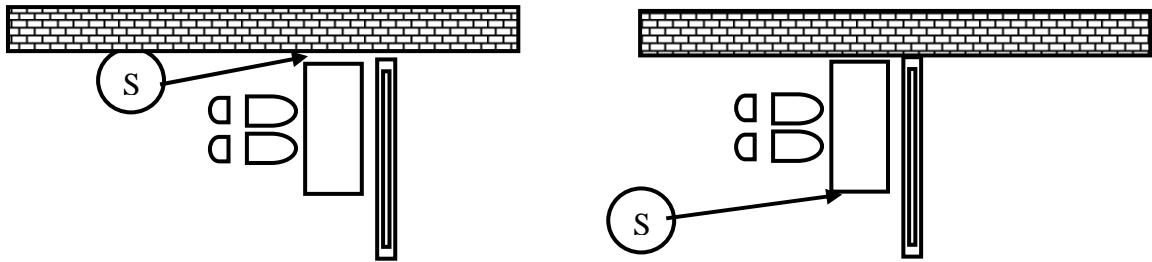


intended

revised layout -
operator in
scatter zoneclutter forces
operator into
scatter zone

The initial design should take account of such potential degradation. Some modern control panels can be fixed to the operator's shield, possibly above the viewing window. A rack or shelf, for storing cassettes off the floor and out of the way, will also prevent damage to the cassettes.

The position of the "expose" switch may be critical to the continued safety of the installation, and the obvious solution is not always the best:



Here, it has been necessary to use a narrow operator shield to allow the patient to reach the bucky. Placing the "expose" switch S on the operator's left is the obvious choice, but this allows the operator to stand with his right shoulder exposed to scattered radiation. Moving S to the right-hand edge of the shield gives him a clear choice between an obviously wrong position and an uncomfortable but safe one.

3.2 Selection of x-ray equipment

3.2.1 Economics

From a study of logbooks, we know that a full-time chiropractor in a new urban clinic generally requests about 1000 - 2000 radiographs per year, reducing (as the patient list matures) to around 300 after 5 years. Utilisation in established part-time or rural clinics may be below 50 exposures per practitioner per year. However the costs of maintenance, quality control, statutory RPA advice, and even processing chemicals, are almost constant.

With a life expectancy of 20 years or more, the capital cost of x-ray equipment is unlikely to be the primary factor in its selection. Performance, reliability, future maintenance support, and ease of use, are the key characteristics.

3.2.2 Statutory requirements

IRR 32 (1) Equipment must be designed, built, installed and maintained so as to restrict patient dose to the minimum required for the clinical purpose. For general chiropractic radiography, this implies:

- at least 95 kV selectable
- at least 120 cm focus-film distance
- total filtration not less than 2.5 mm aluminium equivalent
- selectable mAs with minimum increments of not more than 20%
- a light beam collimator with x-ray/light beam coincidence better than 1 cm at each edge of a 30 cm square field
- an appropriate antiscatter grid
- compatible film/screen combinations of not less than 400 speed for spinal imaging

IRR 32 (2) New or newly installed equipment must have "means of informing the user of the quantity of radiation produced during a radiological procedure." Provided that there is a clear indication that a radiographic exposure has been made, this can be calculated from manually set exposure factors; but if an automatic exposure control is used (this is rare in chiropractic), a post-exposure mAs indicator must be fitted.

IRR 32 (3) and (4) and IRMER 4 (3) (b) The employer must establish a quality assurance programme to ensure that the ALARP objective is sustained.

- (i) All equipment must be subject to an acceptance test before its first clinical use
- (ii) Equipment must be subject to constancy tests at appropriate intervals and it must be possible to assess patient doses
- (iii) Status tests must be carried out after major maintenance.

The RPA will advise on appropriate means of compliance. In general, (i) will be an extension of the initial critical examination, and (ii) can be discharged by careful reviews of image quality and the exposure log book. (iii) requires dialogue between the maintenance engineer and the RPA: the employer must ensure that this takes place and the results are properly recorded.

3.2.3 Specification - x-ray generator

Exposures of more than 1s duration produce significant motion blur in the erect lateral lumbar spine views. At least 150 mA anode current (250 mA for a single-phase generator) is needed to keep exposure times below 1s.

True "high-voltage" films (e.g. chest studies at 150 kV or more) are rare in chiropractic: 125 kV capability is sufficient.

A fixed focus-film distance (ffd) of 150 cm provides a practical compromise

between entrance skin dose and beam geometry on the one hand, and reduction of movement artefact on the other, and allows PA projection.

180 - 200 cm ffd gives excellent lateral cervical images but the reduced dose rate makes it difficult to obtain motion-free images of thicker parts: a variable-ffd system is preferable if long-ffd cervical technique is to be used.

About 5% of chiropractic radiographs are of hands and feet, using a vertical beam. The fraction is large enough that a well-balanced tube head, with a smooth and powerful azimuth rotation lock, should be considered essential. This will also facilitate "textbook" angled-beam studies of the chest and neck. The occasional use of a vertical beam must be considered when designing the radiation protection measures.

Mobile x-ray machines are designed for vertical-beam radiography over a hospital bed, or auxiliary cross-table radiography in a large x-ray room. It is rarely possible to obtain stable and satisfactory beam alignment with a mobile x-ray unit and a vertical bucky in the confines of a chiropractic clinic. Mobile units are not recommended for chiropractic work.

3.2.4 Specification: grid, cassette holder, cassettes

Antiscatter grids are essential for radiography of the lumbar spine.

A moving-grid (bucky) unit allows the use of a coarse (8:1, 35 lines/cm) grid, which is tolerant of focal distance variation and offers low attenuation of the useful beam. Lower ratio (6:1) grids are less suitable for chiropractic radiography, which uses somewhat higher kV values than general hospital radiography.

A stationary grid of 10:1 or 12:1 ratio can be used. The appearance of fine

grid lines is acceptable in chiropractic films, and the scatter "cleanup" of these grids gives better image contrast. However they generally require a higher patient dose than 8:1 units, and are less tolerant of beam misalignment or incorrect focal distance.

For chiropractic radiography, where the spine is usually centred and parallel to the grid lines, a moving 9:1, 36-inch focus grid gives acceptable performance at 150 cm ffd. 10:1 grids with 1 to 1.2 m focal length are common in chiropractic systems, though the appearance of grid lines can be deleterious with a fixed grid. Fixed grids of 12:1 ratio should be used at less than 120% of their specified ffd to avoid excessive lateral shading of the image due to grid cutoff.

Carbon fibre grid covers and interspacers are used for low-kV (e.g. paediatric and mammographic) imaging, but at the moderately high kV values used in chiropractic radiography, the greater scatter absorption of aluminium allows the use of a lower grid ratio, with similar attenuation of the primary beam at less cost.

Dropped cassettes are the main cause of injury to staff in x-ray departments, and impact can damage an expensive cassette. A second-hand bucky may have badly worn catches on the cassette tray: it must be carefully refurbished and inspected before re-use. American "chiropractic cassette holders" are designed to support 14-inch cassettes which are extracted with a loose hook. The system is safe as designed, but any adaptor for European cassettes must hold them in a secure manner.

The number of cassettes should be kept to a workable minimum. It is unusual to require more than four radiographs of any patient in one session. Film must not be kept in cassettes for long periods - it will accumulate radiation

fog and possibly fungal damage. However an empty cassette will not improve patient throughput and may be exposed in error. If throughput is high, it is best to stack the cassettes in order so that the first-loaded is used first. If x-ray use is infrequent, consider leaving the cassettes open and unloaded (in a dust-free environment) until needed.

The fewer sizes of cassette in use, the less probability there will be of any film stock exceeding its expiry date. Narrow films cannot accommodate a pathologically lordotic patient: the use of 18 x 43 cm or even 20 x 40 cm format for lateral lumbar spine studies is often questionable.

As with grids, the difference in radiation transparency between aluminium and carbon fibre cassettes is less significant at higher beam energies and the greater scatter absorption of aluminium may actually be helpful. Agfa Curix (plastic) cassettes have proved durable and easy to use.

Every cassette must be clearly marked to show the type or relative speed of its screens. It is inadvisable and unnecessary to have similar cassettes loaded with different screens, but one or two "fine" or "extremity" systems, in 18 x 24 cm or 24 x 30 cm format, may be useful.

"Graded" screens are not recommended. If it is necessary to demonstrate, for instance, the entire cervical and thoracic spine on one film, a compensating filter or wedge will optimise the image with less patient dose.

3.2.5 Safety standards

New medical equipment offered for sale in the UK must carry a "CE mark", attesting to conformance with the Essential Requirements of the European Medical Devices Directive. But the safety of an x-ray installation depends as

much on the layout and manner of its installation as on its design and manufacture.

Any new x-ray facility must be thoroughly inspected before use, regarding not only its radiological safety (as required by **IRR31**) but also the electrical and mechanical integrity of the final assembly.

Second-hand equipment may be traded without a "CE mark". If it is supplied or installed by a dealer, the Sale of Goods Acts protects the purchaser: it must be fit for purpose, and of "merchantable" quality. Surplus equipment from a public hospital is likely to be robust and well-designed, but a persistent fault - such as inconsistent exposures from a "silvered" tube - may have prompted its disposal. The reputation of the dealer and the availability of spare parts to support the dealer's warranty are important.

Imported personal "tools of the trade" are not subject to mandatory CE certification: liability for their safety rests wholly on the importer. The obvious matter of adapting North American equipment to UK mains supply voltage overlies the more subtle problem of mains supply frequency: inductive components (motors, transformers, brake solenoids) designed for operation at 60 Hz may not perform adequately at 50Hz. Exposure timers may need recalibrating. It is advisable to replace North American power supply cords with wiring to European dimensions and colour codes. Pre-use inspection of imported used equipment requires particular expertise on the part of the inspecting RPA.

3.3 Films, screens and processors

3.3.1 Introduction

Radiation dose in film radiography is determined by

- attenuation of the exit beam by the grid, cassette holder and cassette
- the inherent sensitivity of the film/screen combination
- developer temperature, concentration and immersion time.

The first matter is addressed in chapter 3.2

3.3.2 Inherent sensitivity

Nominal film/screen speed ratings between 400 and 800 are useful for general chiropractic work. Quantum mottle can obscure significant detail if more sensitive systems are used. The extra dose associated with 100-speed "detail" screens is not required in chiropractic spinal radiography: extremity cassettes should not normally be used for lateral cervical studies.

The use of calcium tungstate intensifying screens cannot be justified in chiropractic radiography. Rare-earth systems have superior sharpness for a given sensitivity, or greater sensitivity for a given sharpness.

Green-sensitive ("ortho") film is cheaper than blue-sensitive ("regular") material but the latter is more tolerant of darkroom safelight conditions. The film and screen must be matched, both for spectral sensitivity and contrast. "Green" film in a "blue" cassette requires twice the nominal dose to produce a given image density. Each manufacturer takes a different approach to the distribution of contrast between film and screen: if in doubt, check with the supplier to ensure optimal matching.

It is essential to specify the film type when re-ordering, and to check that the correct material has been delivered: some manufacturers offer "half speed" film for extremity work, with a similar order code to regular material. Where throughput is low, as in chiropractic, it is preferable to use standard film in a "detail" cassette. "Latitude" film is not required for chiropractic radiography.

3.3.3 Processing - manual

Manual film processing in deep tanks is ideal for low-throughput chiropractic radiography. The low temperature and low surface-to-volume ratio of the developer tank give the chemicals a long standby life, and the release of noxious fumes is small. Whilst manual processing is more cumbersome than using an automatic system, the time and cost of maintaining the tanks is negligible.

Films must be developed exactly according to the chemical manufacturer's temperature/time chart. Development by inspection usually leads to excessive exposures, "compensated" by underdevelopment.

Except for the very lowest utilisation (less than one patient per week) the thermostat should be switched on continuously to avoid artefacts from convection and swirling debris in freshly heated developer. In the case of low utilisation it is necessary to heat the developer evenly (some rapid immersion heaters may boil the liquid in contact) and allow any debris to settle before processing any films.

A polystyrene float will usually prevent oxidation well enough to allow the developer to be maintained at its working temperature without serious degradation for several months. However there is certain to be a change in performance as the material ages, leading to declining image quality if the development time is strictly adhered to. This problem can be offset by regular partial replacement, say of 10% per week.

3.3.4 Processing - automatic

Small automatic processors may not be ideal in low-throughput clinics. A shallow developer tray with a large surface area must be thoroughly swept by fresh developer to remove oxidised material before the first clinical film is processed each day: as much chemistry may be consumed in cleaning and replenishment as in processing a small batch of films.

The temperature of an automatic processor should be set at least 34 °C to maximise film speed and contrast without raising the fog level excessively. If the transit time is variable, 3 or 5 minute processing will give a useful increase in film sensitivity and contrast compared with 90 seconds.

The manufacturer's instructions for setting up, adjusting, checking replenishment rates, cleaning, and maintenance, must be adhered to. Almost every reported "x-ray machine failure" in chiropractic is eventually traced to inadequate replenishment or low developer temperature (damaged or wrongly calibrated thermostat, heating element failure) in an automatic processor. The flexible pipes from the replenishment tanks to the processor should be checked shortly after installation, whenever the tanks are moved, and during any period of hot weather - they are prone to soften and kink, gradually restricting the flow of chemicals, if they are under any mechanical stress.

3.3.5 Processor QA

Quality assurance in film radiography depends almost entirely on maintaining constancy of the film processor. This may be quickly assessed by processing a recently pre-exposed test film and comparing it with a reference film. Automatic processors should be checked as soon as any variation is detected in image quality, and in any case at least weekly. Manual processing tanks should be tested at least monthly.



typical test strip appearances

3.3.6 Waste disposal

Local water and sewage companies have differing rules regarding the disposal of small quantities of waste photographic chemicals. Discharge to the sewers may be permitted through a silver trap, obtainable from the processor maintenance company.

If disposal to the sewers is not permitted, it is important to store bulk collection tanks where they can be easily removed when full, and preferably not in the darkroom. Bulk photographic chemical waste is classified as hazardous and must be removed by a specialist. The cost of haulage (usually quoted as "per trip" rather than "per litre") reflects the administrative overhead of dealing with small quantities of waste. An undisturbed drum, if kept clean and properly closed, presents no great hazard if it is kept in a shed or garage until the maximum trip load has been accumulated.

3.3.7 Darkroom cleanliness and discipline

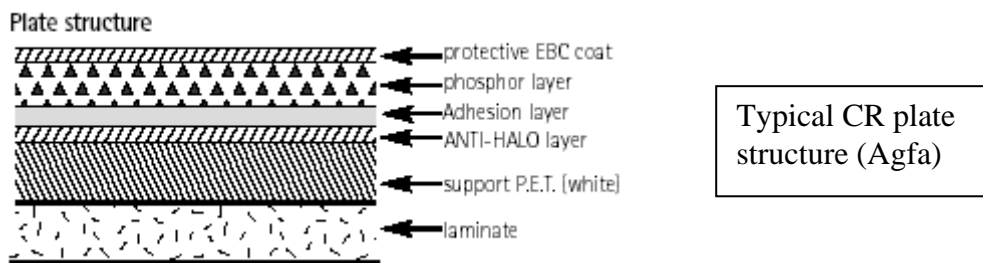
Almost every "xray machine fault" the present author has investigated in the last 25 years has been due to a fault in the darkroom. Photographic chemicals are corrosive and toxic (no open buckets or trays), and the room must be kept at least as clean as a kitchen (but the preparation or consumption of food and drink is prohibited by law in darkrooms), dry (check plumbing joints regularly) and properly ventilated. Anything on the floor is in the wrong place. Electrical extension cables are hazardous on a potentially wet floor. Vacuum cleaners and brooms (and pets - at least one dog basket and even a cat flap have been found in chiropractors' darkrooms) bring dust into the room and must not be stored there. It must be possible to reach all parts of the processor without straining or stooping (check the ergonomics with a chiropractor), whether to insert a film or to remove the racks for cleaning. Fresh and used chemicals must be properly segregated and there must be suitable protective clothing and eyewear for handling chemicals - read the "COSHH" warnings on all chemical supplies.

Processor cleaning and replenishment must be scheduled, and undertaken by trained operators only.

3.4 Computed Radiography

3.4.1 The CR process

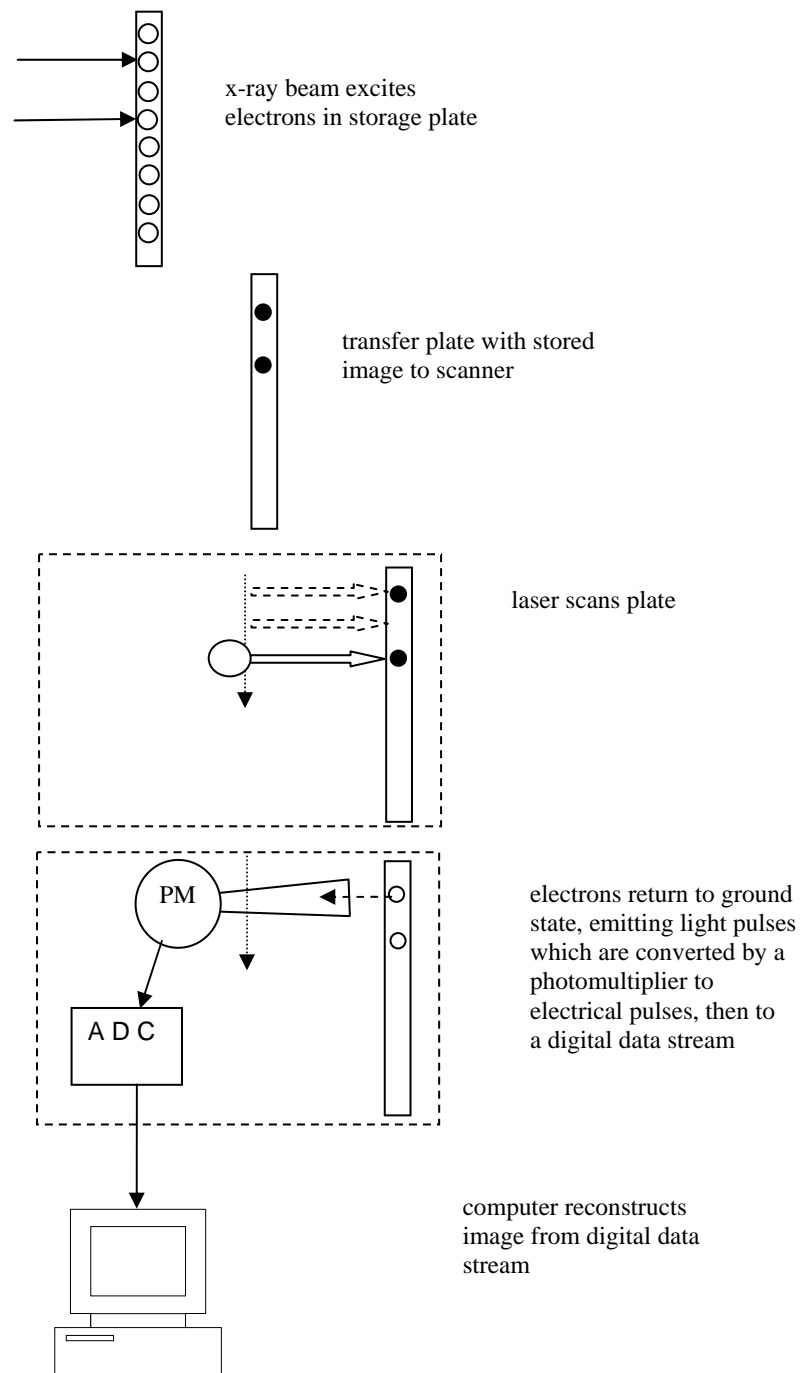
A CR cassette is similar in appearance and construction to a film cassette. However in place of the screen/film/screen sandwich, it contains a single thick sheet of material impregnated with a “photostimulable” phosphor and covered with an optical coating.



The phosphor absorbs x-radiation with similar efficiency to an intensifying screen but, instead of converting the x-ray photon energy instantaneously to visible light; it stores some energy by trapping excited electrons within the crystal structure. If these electrons are now stimulated by visible light (usually from a red laser) they return to their ground state, emitting light (usually in the blue region of the spectrum) as they do so.

After exposure to the x-ray beam, the phosphor plate is transferred to a scanner where the stored x-ray image is extracted by a moving laser beam. The blue light emitted by the returning trapped electrons is converted to an electrical signal by a photomultiplier, and the output voltage is fed to an analogue-to-digital converter. The resulting data stream is transferred to a computer memory and displayed on a screen as shades of grey, corresponding to the x-ray image.

The image characteristics can be manipulated by software to alter such parameters as brightness, contrast, edge enhancement and colour (black/white inversion or false colour - mapping intensity to colour rather than grey level)



Steps in the Computed Radiography process

3.4.2 Implementation of CR technology

The simplest CR systems, originally intended for mobile military and veterinary use, have a compact cylindrical scanner, about the size of a desktop printer. The phosphor plate is extracted manually from the cassette and wrapped around the scanner drum, and the scanner mechanism drives the plate past the laser. This equipment is compact, remarkably robust, and fairly inexpensive, and is favoured by dentists: small flexible plates can be wrapped in plastic film for intraoral radiography. The phosphor plate must be erased (usually in a drawer under an intense fluorescent lamp) and replaced in the cassette. This system has found favour in single-handed chiropractic clinics where the operator can adequately control the working environment, but in a busy multi-handed practice the plates are prone to damage.

Hospital-type CR scanners are somewhat larger and require careful sitting on a rigid, level surface. They extract, scan, erase and replace the phosphor automatically and are preferred for multi-handed practices.

Integrated CR systems incorporate the scanning mechanism within a special housing that includes the phosphor plate and an antiscatter grid. This arrangement is necessarily less adaptable than a cassette-based receptor but in fixed-geometry applications (such as the majority of chiropractic radiography) it eliminates the need for (and potential damage arising from) handling the CR plate.

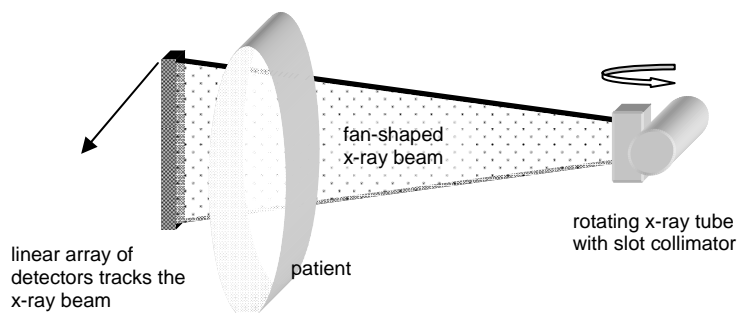
The latent image in a CR plate is prone to fading, and the plate remains sensitive to radiation fogging after exposure. CR plates should be scanned within minutes rather than hours of exposure.

3.5 Direct digital radiography (DR)

3.5.1 DR receptors.

There are two general types of DR receptor: flat plate and linear scanner. Flat plate receptors have a two-dimensional array of x-ray sensitive elements covering an area of about 43 x 43 cm (the size of the largest conventional film cassette). These elements may be photosensors covered with a phosphor that converts x-rays to visible light (similar to a film and screen system), or a photoconductor that converts x-ray photon flux directly to electrical charge. The 2-dimensional array of electrical signals is read out sequentially, converted to a digital data stream, and processed in much the same way as a CR image. The image is acquired by the plate in a single exposure and reconstructed in a matter of seconds. It is possible, by sacrificing some detail, to approach real-time image acquisition, making the flat plate receptor a convenient replacement for a fluoroscopy system, but such applications are unusual in clinical chiropractic.

The linear scanner is electronically simpler but mechanically more complex than a flat-plate DR system. A single strip of photoreceptors is scanned across the patient, synchronised with a narrow "fan" beam of x-rays. Readout is continuous and the image reconstruction process is similar to CR and flat-plate DR.



Whilst it may take 3 - 5 seconds for a scanning system to cover the width of the patient, the narrow beam only exposes each part of the patient for about two milliseconds. Thus gross movement of the patient may result in some distortion of the overall geometry but does not generally compromise image sharpness.

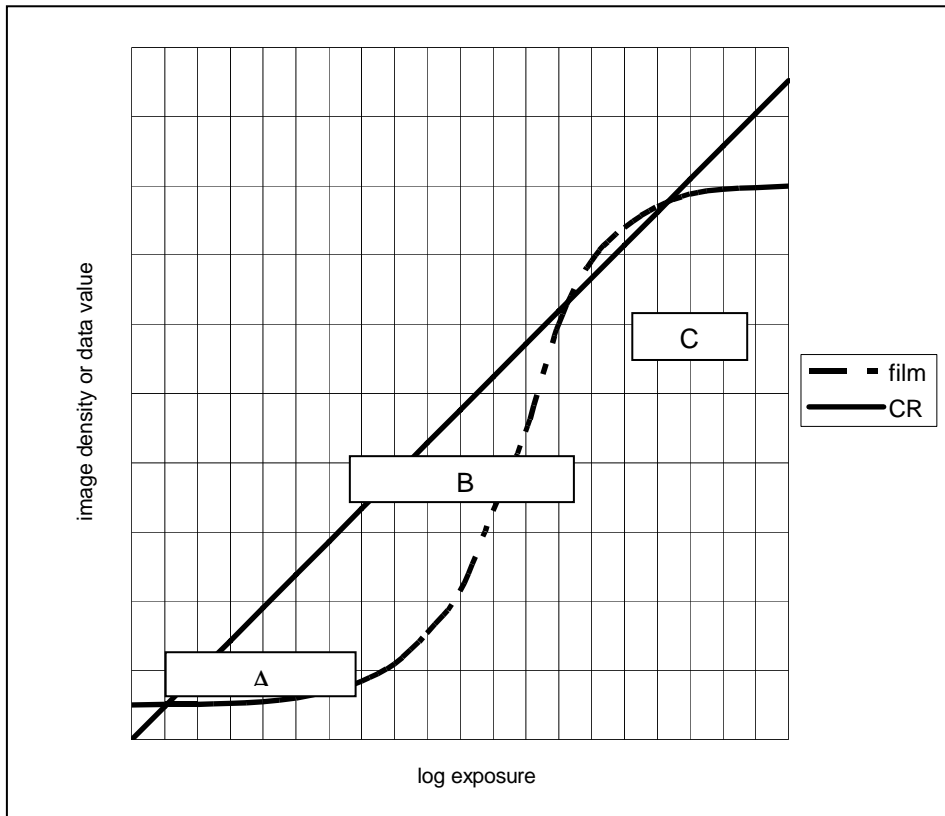
A further refinement of the slot-scan system uses parallel rectilinear movement of both the tube and the detector. This has the advantage of not distorting the image in the direction of movement, so allowing very accurate measurement of e.g. femur length. At the time of writing such systems have not been installed in chiropractic clinics (on grounds of size and cost) but may be encountered in trauma and orthopaedic assessment units.

3.6 Advantages and disadvantages of digital radiography

3.6.1 Technical considerations

Digital imaging is certain to become the preferred modality for chiropractic radiology. However there are several important differences between film-screen (FS) radiography and digital image acquisition that demand a different approach to image optimisation from the body of knowledge and experience that has accumulated over a century of film radiography.

Storage phosphors and DR photodetectors have a linear response to x-ray dose extending well over a factor of 10,000 between background noise and saturated black. This is quite different from the limited, nonlinear response of a film/screen system:



The S-curve of the film/screen system is responsible for the familiar appearance of a clinical x-ray film:

- A** - areas of low exposure (e.g. behind dense bone) appear clear white
- B** - the clinically significant area is rendered with high contrast – small variations of exposure produce large changes in blackening
- C** - overexposed areas are black with no detail recorded

The density range of a film radiograph, i.e. the useful "height" of zone B, is almost 3000:1. The useful exposure range is about 1000:1, i.e. any part of the cassette receiving a dose of less than about 0.1 μGy will leave the film effectively white, and any part receiving more than 100 μGy will produce a saturated black image.

Films, screens, viewing systems and exposure charts have been developed over many years to optimise the image presentation of clinical radiographs in "one shot" - the image emerging from a well-maintained processor is instantly recognisable.

The linear response of a CR plate extends from zero to about 10,000 μGy . Thus in the image data:

A - areas of low dose are populated by noise from the electronic system, inadequately erased previous images, or background radiation (scatter, natural background)

B - software processing is needed to increase the image contrast of the clinically significant data

C - there is no practical indication of "overexposure" - almost any part of the body could be radiographed with a chiropractic x-ray machine at its maximum settings and an image then retrieved by software manipulation.

DR image data has broadly similar characteristics but the detectors are not susceptible to "memory" of previous images nor to the acquisition of background radiation fog over time, and may saturate at lower doses (though still higher than film).

Digital imaging software packages include a number of standard algorithms for optimally displaying e.g. bone, soft tissue, bone margins, etc, and these are usually accessed through anatomical menus. In practice this can make even DR acquisition seem rather tedious compared with using an automatic film processor: the system will probably require the patient's name to be typed in, then the exact projection selected, before it will accept the plate.

However it is important to work through each step correctly. If not, it will be impossible to retrieve the image from possibly thousands of unnamed images stored in the computer, and the presentation will be excessive in contrast, flat, or noisy.

Spatial resolution, the "fineness" of an image, is rarely a significant consideration in the choice of a chiropractic imaging technique since motion blurring will limit the object fineness in any freestanding study. In principle, direct-conversion flat plate technology could resolve detail finer than 10 line pairs per millimetre - the practical limit is set by the bandwidth of the data link and the time taken to process a large image. Systems that use an intermediate phosphor, whether CR or DR, are limited to coarser resolution by the spreading of the visible light emitted by the phosphor. In practice, however, it is not generally necessary to resolve more than 3.5 lp/mm over a 35 x 43 cm field and most commercial CR and DR systems achieve this, with images of similar clinical quality to 600-speed FS presentation.

3.6.2 Convenience and running costs

There is no doubt that CR or DR systems require substantially less space for image processing and storage, present images in a matter of seconds, and have far lower maintenance costs than film radiography. The initial capital cost can be offset against the space reduction alone, compared with film, and CR is likely to be more cost-effective in a rented "high-street" clinic after as little as two years.

There are no essential consumables, CR plates are as convenient and versatile to use as film cassettes, images are stored on disc for rapid recall and can be copied to a CD or transmitted over the internet, and post-exposure manipulation can enhance visualisation of clinically significant aspects of the image.

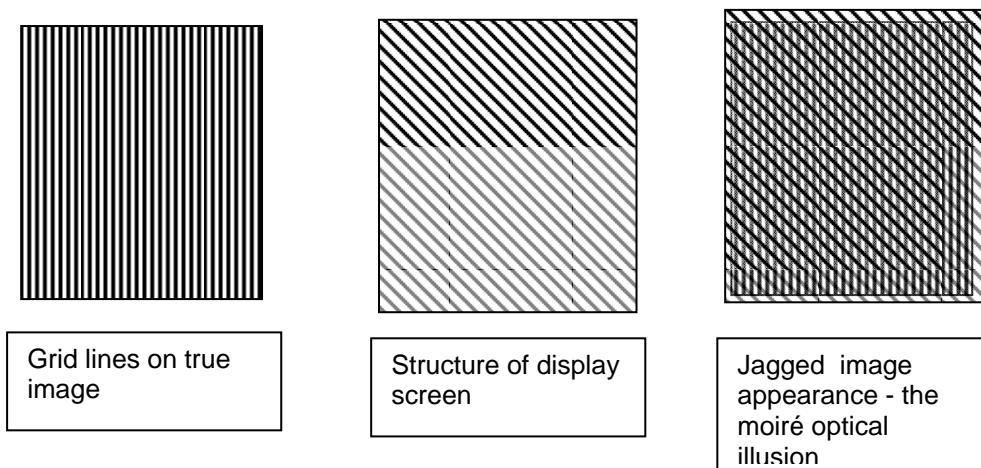
The patient can be supplied with copy images in a matter of minutes by burning a CD, and images can be sent to a consultant by email.

3.6.3 Patient dose

Whilst a CR or DR system has a linear dose/signal response down to zero dose, this cannot be exploited in practice to reduce patient dose compared with a good film-screen (FS) system. Screen speeds in excess of 800 produce unacceptably "speckly" images ("quantum mottle") as the number of x-ray photons per unit area reaching the screen is insufficient to give the impression of continuous blackening in anything other than the "direct beam" areas, and it is unusual to find screens faster than 600 in clinical use. Where clinicians have been given a free choice of effective speed for a CR or DR system, researchers have generally found a strong preference for the appearance of 400 - 600 speed images, with higher sensitivities being considered too noisy for confident diagnosis.

"Dose creep" is a common phenomenon in clinics using CR or DR: there being effectively no upper limit to image receptor dose, operators are tempted to produce "better" images by increasing the signal/noise ratio, i.e. increasing patient dose. It is less common with LS systems which are less tolerant of overexposure and tend to use preset exposure factors which are quite different from those of FS radiography.

The effect of grid attenuation on patient dose is important. If the exposure times are reasonably long, an 8:1 grid in an oscillating bucky will provide adequate scatter reduction for film radiography. However a CR plate is significantly more sensitive to low-energy scatter photons than an FS system, so a higher grid ratio will normally be required, with consequently greater attenuation of the primary beam. Whilst a 10:1 stationary grid can be used with FS receptors (and even an 8:1 stationary grid may be acceptable for chiropractic films as the "grid lines", though not aesthetic, generally do not interfere with image interpretation), the interlacing of grid lines and the regular pattern of pixels in a digital image display can produce masking moiré fringes which do degrade image quality:



It is therefore necessary to use an oscillating bucky with a medium grid, or a fine-line stationary grid with a CR or DR system, and the potential reduction in patient dose compared with FS is not realised in practice.

Linear scanning (LS) DR systems *do* offer the potential for reduced patient dose compared with FS. The narrow fan x-ray beam generates no first-scatter from regions on either side of the immediately-irradiated strip of the patient, and the narrow image receptor is buried in a collimator precisely aligned to the primary beam, so is insensitive to secondary scatter.

It is normal to use somewhat higher kV settings for LSDR than other modalities, both to compress image contrast and to allow scatter originating *within* the illuminated strip to be reduced by filtration or ignored by using a high-energy selective phosphor.

There is little published data on effective dose in LS radiography in chiropractic, but it is likely to be about 30% less than required by other systems for comparable image quality.

3.6.4 Post-processing and image display

The permanence of a film image is helpful in diagnosing faults in the imaging process, such as incorrect exposure factors or inadequate development. However provided that "dose creep" is avoided by rigorous application of exposure protocols, it is considerably easier to extract images of diagnostic value from digital data. The requirement for fault diagnosis is somewhat reduced compared with film. (Modern x-ray generators are most unlikely to deliver "wrong" kV or dose: manufacturers report "no failures in 15,000,000 exposures" as typical, and the average chiropractor is unlikely to make more than 25,000 exposures in a lifetime.)

Provided that the digital image contains enough data (i.e. the dose was sufficiently large) it can be manipulated by altering the "window width" (contrast) and "window level" or "threshold" - i.e. selecting the mid-point of the image data to be displayed - in effect the mean density of the image - to allow the clinically significant data to be optimally displayed.

The human eye can accommodate the entire range of image brightness from a well-lit film viewer, so FS imaging can produce a useful image contrast range of the order of 2000:1 under most conditions and 3000:1 when optimised.

However even the best medical computer display screens are severely compromised by ambient light as their inbuilt backlight intensity is limited, and it is rare to find digital image displays in small clinics that actually yield more than 200:1 contrast range.

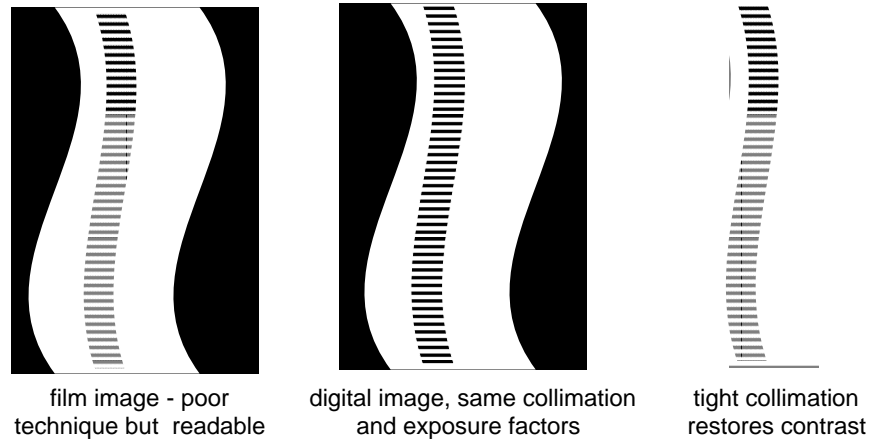
The design of any clinical examination room must be considered with a view to optimal viewing conditions for reporting x-ray images. In general this means no direct sunlight falling on the viewer, avoidance of spotlights and desk lamps, and muted or dimmable general lighting. Film viewers must be vertical and digital image screens should preferably be well above desk height and tilted slightly downwards - a conventional "laptop on a desk" cannot be considered optimal.

3.6.5 Artefacts and suboptimal digital images

Normal clinical software attempts to derive and present a film-like image from the data stream. This usually involves recognising the intended image area and normalising the data points within that area to fully utilise the dynamic range of the display screen. It is therefore essential to collimate the primary beam very carefully to the region of interest and ensure that the incident dose and kV are high enough for the exit dose to exceed the system noise level at all points of interest.

A "muddy" image often results from setting the x-ray collimator too wide. The computer recognises the sharp edge of the primary beam and attempts to display all the data within that that frame, including the maximum black, in "zone B" as though it were of clinical significance. Thus the information in the region of true clinical interest is compressed towards the white end of the display range.

Additionally, scattered radiation from the direct beam increases the background fog more than in a FS system, so the inherent contrast of the clinical image is also degraded.

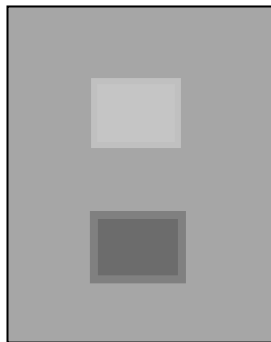


Persistent thin white lines at an arbitrary angle to the edge of the image indicate a cracked CR plate. Thin lines precisely parallel to an edge are due to scanner problems, usually mechanical or optical. Diagonal lines on any digital image may be due to moiré fringing (failure of bucky movement, incorrect choice of static grid, grid lines parallel to scan direction) or electronic interference.

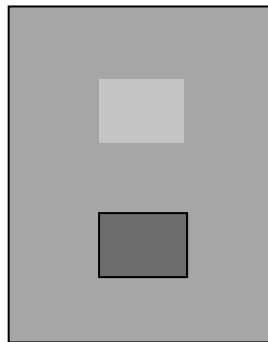
"Ghosts" in CR images may be due to inadequate erasure (look for anatomical shapes in the ghost image) or scattered radiation forming an image on an improperly-stored cassette (look for "mechanical" shadows of other cassettes, etc.)

"Spots" and general fog accumulate on CR plates from natural background radiation. Plates should preferably be erased immediately before use, and certainly every week, to minimise background fog.

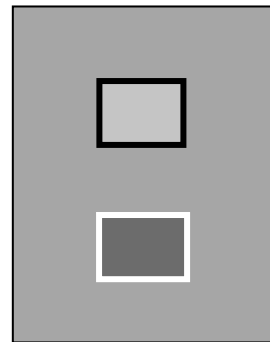
Excessive use of edge enhancement can generate "ringing" artefacts with the appearance of luxations or hypercalcifications



unprocessed



optimised



"ringing"

4.1 Indications for chiropractic radiography

4.1.1 The meaning of "justification"

The underlying ICRP principle is that any controllable exposure to ionising radiation must be justified *in advance* by consideration of the likely benefits to those exposed and to society at large, and the likely detriment to those exposed.

IRMER 5, 6 The referrer must supply sufficient data to enable the practitioner to decide whether there is a sufficient net benefit in the prospective radiation exposure. The practitioner is "responsible for the justification of a medical exposure." "No person shall carry out a medical exposure unless -

- (a) it has been justified by the practitioner as showing a sufficient net benefit giving appropriate weight to the matters set out [elsewhere] and
- (b) it has been authorised by the practitioner...."

The precise but contorted use of the participle in IR(ME)R reflects its origins in a European Directive. The French verb *justifier* is used in a sense closer to that of the ICRP principle, i.e. an active and prior process of consideration and adjustment, rather than the adjectival, passive, and retrospective use of "justified" in idiomatic English. Thus the practitioner is required to consider the likely benefits and risks of a prospective exposure and if in his sole opinion the likely benefits outweigh the likely adverse consequences of an individual exposure, he can authorise it.

There is no provision in IR(ME)R for retrospective or third-party consideration of the clinical value of an individual exposure (i.e. the colloquial notion of "justified"), nor is it logical to undertake such an exercise. The referrer cannot know in advance what a radiograph will reveal, so some proportion of requested images will not contribute materially to the patient's diagnosis or treatment (though exclusion of a well-founded concern, such as a "recent fracture" is of course a positive contribution, and the absence of radiological anomaly in the spine may suggest an abdominal tumour as the cause of back pain).

It can be argued that if every requested image proves clinically useful, the referrer is probably underutilising the radiological facility at his disposal and failing to radiologically diagnose evident pathology in those patients he does not refer for x-ray. Equally if very few images are of value, he should perhaps be more critical in his clinical examination. But these are statistical considerations for clinical audit, not *a posteriori* criteria of good management of an individual case.

4.1.2 Referral criteria

IRMER 4, (3) states: "The employer shall establish -

- (a) recommendations concerning referral criteria for medical exposures, including radiation doses, and shall ensure that these are available to the referrer;...."

There are 15 recognised common indications for radiographic examination in chiropractic, (which may conveniently form a "tick list" of referral criteria)

These conditions are reflected in the European Union document "Radiation Protection 118 - Referral Guidelines for Imaging" (ISBN 92-828-9454-1) and are sufficiently indicative that it could be considered negligent to initiate palliative or therapeutic manipulation without an x-ray or MRI examination of a patient presenting with any of the above conditions.

Patient over 50 years old

Significant injury/trauma

Neuromotor deficit

Unexplained weight loss

Known or suspected inflammatory arthropathy

Drug or alcohol abuse

History of malignancy

Use of steroids

Fever of unknown origin (greater than 100°F / 37.8°C)

Scoliosis

History of surgery in region

Failure to improve with conservative care

Inconsistent or equivocal biomechanical examination findings

Evaluation of complex postural or biomechanical disorders

Limited examination due to pain

"RP118" is based on a substantial and continuously-reviewed body of work led by the UK Royal College of Radiologists and may be considered authoritative. Being addressed to primary care and hospital doctors, it is somewhat biased towards the diagnosis of early acute presentation and recent trauma so its recommendations are indicative but not definitive for chiropractic. "Back pain" is not considered a sufficient indication for radiological examination of an otherwise healthy adult since the majority of early presentations recover spontaneously.

However as most chiropractic patients present with chronic conditions, it can be argued that examinations listed as "not routinely indicated" in RP118 may be more often appropriate in chiropractic. Significantly, under "Paediatrics", RP118 carries an important and often-forgotten reminder that "Back pain is uncommon in children without a cause..." and x-ray examination is indicated.

4.1.3 "Spinal screening", research, and experimental diagnostic techniques

IRMER 6, 7 The irradiation of persons without indicative clinical symptoms is prohibited except in the course of a health screening programme (defined as early diagnosis in population groups at risk) or a research programme approved by an Ethics Committee. Even where such an exposure is permitted, the Regulations imply that every individual exposure must be authorised by a practitioner.

It is unlikely that a chiropractic screening programme, say for a factory, including x-ray examination of the entire workforce, would be permitted.

Healthy volunteers in a clinical research programme must be subject to agreed "dose constraints", and the practitioner in charge of the exposure must satisfy himself that each is a genuine volunteer and has been adequately informed in advance of the risks of the exposure.

Experimental diagnostic procedures must be designed with individual target doses for each patient.

The RPA and medical physics expert (MPE) must be consulted in the planning stage of any screening, research or experimental diagnostic procedure. Their independent estimates of dose, risk/benefit, and procedure control, will be required evidence for the Ethics Committee

4.2 Techniques for chiropractic radiography

4.2.1 Statutory requirements

IRMER 4 (2) The employer must ensure that "written protocols are in place for every type of standard radiological practice for each equipment." The word "protocol" is not defined but as it is implicitly equipment-specific the only logical interpretation is that each clinic must have

a "house style" of presentation and
an appropriate exposure factor chart, at least for the most common projections

It is generally practicable to adopt 150 cm focus-film distance (ffd) for all erect spinal studies. This represents a compromise between exposure duration (reduced at shorter ffd) and entrance skin dose (reduced at longer ffd) and is within the tolerance of the most commonly used antiscatter grids.

A minimum protocol would include the instruction to "collimate within the film size marked on the bucky", but a more explicit house style (e.g. "no tilt, centre on L3/4, collimate to symphysis pubis, select 78 - 84 kV, read mAs from chart") is preferable. Reference to a chiropractic or radiographic textbook (which must be available in the clinic) is unequivocal and strongly recommended.

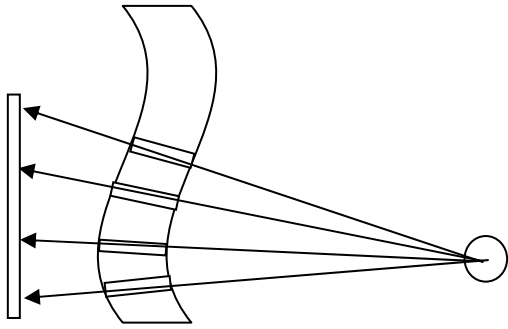
A universal exposure factor chart is appended at 7.8. This may be used to devise a simple list of commonly-used factors for any clinic. It is inadvisable to display more than one factor chart at the operator's position, and that which is displayed must be calibrated for the particular installation.

4.2.2. Optimisation

IRMER 7 (3) Standard "textbook" radiographic techniques can be modified to minimise dose or maximise the yield of relevant clinical information in support of chiropractic.

Free-standing lateral cervical studies are prone to motion blurring of the upper vertebrae, though a foam wedge between the ear and the bucky does reduce movement. If high mA settings (400 mA or more) are not available, the use of high kV technique (90 - 95 kV) should be considered: the loss of object contrast compared with "medical" films at 70 kV may not be significant, but reducing the exposure time from say 0.3 s to 0.08 s will substantially improve the bone definition in a free-standing posture.

For all but the most obese patients, PA projection of the lumbar spine is preferred for chiropractic radiography as the divergence of the x-ray beam is in the same sense as that of the intervertebral spaces. There is less "overlap" of vertebral margins than in AP projection and the images are easier to interpret. The patient can lean against the vertical bucky, providing some compression of adipose tissue and stabilising him in a natural posture, but it is likely that patient movement will still blur the trabecular patterns and the absence of that information alone should not necessitate a repeat film. Most significantly, gonad dose is greatly reduced (for both sexes) by PA projection and scrotal shielding is not required.

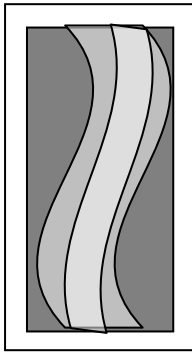


PA projection, the usual presentation for "chest films", can sometimes be considered for radiography of the thoracic spine. Whilst it will increase the overlap of vertebral shadows in a normally kyphotic patient, it provides comfortable compression for large breasts, and minimises breast dose.

4.2.3 Restriction of beam area

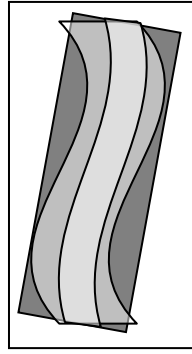
The limits of collimation within the patient's shadow are a matter of clinical choice, but the "house" region of interest (roi) must be determined by clinical decision for each clinic. If the primary beam is wider than the patient, scattered radiation will degrade the image (seriously in the case of digital imaging - see 3.6.5) but without greatly affecting patient dose. However if the beam is longer than the roi it will expose radiosensitive organs (eyes, breasts, pancreas, gonads) without contributing any information to the image. If the beam is routinely collimated within the film size, it is preferable to mark the projected film size on the bucky and collimate inside that outline, or at least use the calibrated markings on the collimator, before positioning the patient.

Sensible use must be made of the rotating collimator, not only for lateral cervical films but also where appropriate to minimise the irradiated area for, say, a pathologically lordotic lumbar spine.



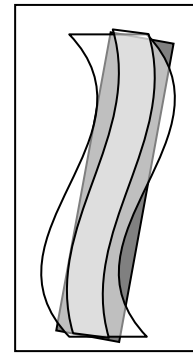
50% direct radiation: scatter
reduces image contrast

100% patient irradiation



25% direct radiation
improved image contrast

100% patient irradiation



5% direct radiation
optimum contrast

50% patient irradiation
reduced dose

Reduction of direct beam irradiation of the image receptor will *significantly* improve digital images (see also 3.6.5)

Collimator accuracy must be checked regularly to ensure, for instance, that AP open mouth images do not include the orbits. X-ray/light beam coincidence of better than ± 7.5 mm at each edge of a 16 x 20 cm field at 150 cm ffd is easily achievable, but collimator mirrors can warp or shift out of alignment in use.

Post-patient collimation does not affect patient dose but can improve image quality by absorbing primary radiation that would otherwise degrade the image. A strip of lead rubber between the legs will sharpen a bilateral knee study, and an L-shaped lead mask can enhance the diagnostic value of an AP shoulder film. Post-collimation or the use of a shaped blocker (see below) is particularly useful in reducing the input range of a digital image and thus improving image contrast. If the primary beam has been properly collimated, there is no virtue in cropping a digital image - indeed to do so would remove the evidence of primary collimation and imply that the technique had not been optimised.

4.2.4 Filters, wedges and blockers

A copper/aluminium filter is useful for reducing ovary dose in AP and PA lumbar spine studies. The aluminium side of the filter is placed towards the patient.

Radiographic visualisation of long sections of the spine is compromised by the variable thickness and density of the overlying soft tissue. "Points wedges" can be attached to the collimator to modulate the intensity of the primary beam and thus reduce the contrast range of the image. They should always be used for long AP open-mouth-cervico-thoracic studies and are very effective in lateral lumbar studies, particularly of women with narrow waists and wide hips.

The lung fields may be included in a thoracic spine film by adding appropriate filters to reduce the entrance dose to either side of the vertical axis of the primary beam. "Lung blockers", which minimise breast dose and provide an "inverted T" shaped field, should be used if it is necessary to demonstrate the whole spine and pelvis on a single film.

Graded "spinous process" filters are useful for demonstrating the posterior processes in lateral view, particularly if multiple fractures are suspected. Careful use of digital postprocessing is also helpful here.

If an AP whole skull view is required, considerable dose will be saved, without compromising the diagnostic value of the film, by the patient wearing protective spectacles. 1 - 2 mm lead, fitted to a plastic sunglasses frame, is well tolerated. Eye dose in PA skull views is generally tolerable if an image of the orbits is required, but it should not be necessary to include the orbits in a lateral cervical study.

4.2.5 Standard exposure chart

IRMER 4, 7 Diagnostic reference levels, i.e. standard doses for common examinations, must be established and must not be routinely exceeded. This is most simply accomplished by adopting a standardised exposure factor chart which allows the operator to calculate the exposure factors required for any projection of any patient.

A universal exposure chart, based on the well-known Siemens Points system, is appended to these Notes (7.9), along with instructions for calibrating it to a new or existing x-ray installation. The standard chart must be calibrated for each particular installation by adding or subtracting "system correction" points.

Exposure factors are not transferable between x-ray installations, however similar they may appear. Small variations in processor temperature or mains supply impedance can vary the required factor by one or two "points".

Using the standard chart, with a 400-speed film/screen combination, 150 cm ffd, and a properly controlled processor, the entrance surface dose to a "standard patient" should be less than the Diagnostic Reference Level values given in Chapter 4.3.1

4.3 Patient doses, paediatric and pregnant patients, and consent

4.3.1 General

Subject to the overriding principles of justification, optimisation, and ALARP, there is no statutory limit to the dose that a patient may receive.

IRMER 4 (3) Every employer must adopt "diagnostic reference levels" (DRLs) and ensure that these are not normally exceeded in the investigation of average patients. The DRLs for plain film radiography are expressed as entrance surface dose (ESD). UK Department of Health consensus values (from www.dh.gov.uk, 2007) and other reasonably achievable DRLs for the common chiropractic examinations are set out below, with an indication of the nearest conventional technique factors that would normally deliver the DRL in a single exposure at 150 cm film-focus distance, from a high-frequency or 12-pulse generator. It is unusual for any chiropractic exposure chart to exceed or even approach these values.

Region	projection	DRL (mGy)	kV	mAs
skull	AP	3	77	75
	Lat	1.5	73	40
C-spine	AP	2	70	60
	Lat	1.5	70	50
T-spine	AP	3.5	77	90
	Lat	10	81	250
L-spine	AP	6	81	150
	Lat	14	90	240
	L5/S1	26	90	500

The pursuit of ESD reduction should not compromise the clinical utility of the images. High kV reduces contrast, and fast screens produce "noisy" images.

Compliance with DRLs can be proved by maintaining a comprehensive journal (the exposure log) in which the technique factors are noted for every exposure. "Specific output" data from the latest inspection report can then be used to estimate ESDs.

4.3.2 Calculation of entrance skin dose, organ dose, and effective dose

If the inspection report refers to a focus-detector distance of a cm, and the actual focus-skin distance is b cm, then the ESD, allowing for backscatter and geometric correction, is approximately

$$\text{ESD} = \frac{1.2 \times K \times M \times a^2}{b^2} \quad \text{mGy}$$

where K is the reported specific output (mGy/mAs) at the set kV, and M is the actual mAs value used.

The calculation of organ and summed-organ (effective) doses is rarely required and is normally a matter for the attention of the RPA or MPE. The information required to calculate organ dose for a given exposure is

kV

mAs

fsd

filtration

patient thickness

presentation (PA, AP or lateral)

position of the organ relative to the primary beam (this should be clear if the beam is collimated within the image receptor boundary).

4.3.3 Paediatric patients

IRMER 7 (7) (b) The practitioner and the operator are required to "pay special attention to.....medical exposures of children". It is not possible to give explicit guidance on this matter: a 14-year-old may be of adult stature and possibly even pregnant, and the x-ray dose required to form a clinically useful image of a muscular adolescent will be necessarily greater than that for a slightly built 70-year-old. However it is worth bearing in mind that

- gonads and breasts of young patients should as far as possible be excluded or protected from the primary beam
- "babygrams" - showing the whole body of a child on a single film - are unlikely to be authorised in chiropractic (though a full-spine scoliosis study may be needed occasionally)
- it is most unusual for a child to present for chiropractic treatment with clear radiological contraindications to treatment. History and clinical examination may suggest that a case where radiological investigation is indicated, should be referred elsewhere in the first instance.

If there is a clear indication for radiographic examination of a child, factors should be selected to give the shortest possible exposure - movement artefacts are more problematic with younger patients. The exposure should be rehearsed by putting the anode into "prep": the noise of the x-ray tube may otherwise startle a nervous child. Children are however generally tolerant of restraint bands and willing to cooperate.

4.3.4 Pregnancy

IRMER 7 (7) (e) requires the practitioner and operator to pay special attention to the exposure of females "where pregnancy cannot be excluded."

Chiropractic radiography is a low-dose procedure and falls within the scope of the "28 day rule". The risk to a foetus from two lumbar spine radiographs is negligible in comparison with the normal risks of pregnancy if the exposures are made within 28 days of onset of the last menstrual period. It is nevertheless essential to obtain and record the patient's informed consent.

IRMER 6 (3) (c), 7 (7) (e) Any female patient who might be pregnant must be asked "are you or could you be pregnant?" If the answer is an unequivocal "no" she should sign a Release form. If she gives any other answer she must sign a Consent form before she may be radiographed. The forms are combined in a single **model** document appended to these notes at 7.4. Consent must be informed. The practitioner must explain the risks of radiation in pregnancy to the patient before she signs the Consent form. *In any case, always ask and record the date of the last menstrual period.*

A useful concept in quantifying radiation risk is the Background Equivalent Radiation Time (BERT). Natural background radiation in the United Kingdom delivers about 2.5 mSv/year to each inhabitant. BERT is the time required to receive a dose equal to that from a given x-ray examination, from natural background. A table of typical BERT values is appended to these notes (6.5).

The foetal dose from a maternal lumbar spine series, using typical chiropractic technique factors, is about 1 mSv, equivalent to 5 months' exposure to background radiation. The additional foetal radiation dose from a lumbar spine series is about the same as that of carrying the baby to term in Cornwall compared with Essex.

The consensus publication "X-rays - how safe are they" from the National Radiological Protection Board, College of Radiographers, Royal College of Radiologists and Royal College of General Practitioners (2001) described the associated lifetime risk of cancer per examination thus

x-ray examination	risk	descriptor
Chest, arms, legs, hands, feet	< 1 in 1,000,000	<i>negligible</i>
Skull, head, neck	< 1 in 100,000	<i>minimal</i>
Hip, spine, pelvis	< 1 in 10,000	<i>very low</i>

It is recommended to use these adjectives and no others if numerical data is not understood.

4.3.5 Consent

The United Nations Human Rights Charter requires any medical examination to be carried out under conditions of informed consent. This philosophy was taken into consideration in drafting the European Directives on radiation protection, but there is no explicit requirement in IRMER to obtain or record consent for a radiographic examination.

The pregnancy "release/consent" form (see 4.3.4 above) attests to compliance with IRMER and general good practice in respect of female patients of childbearing age. It is not possible to radiograph an adult in a free standing posture without the patient's willing cooperation, but contrary allegations are occasionally made so is it wise to record a defence against the General Chiropractic Council. You should, having presented relevant clinical findings, seek the patient's consent prior to taking x-ray films and obtain the patient's written consent (or that of his guardian). See form in section 7.4

4.4 Recordkeeping

4.4.1 General

The employer, in a practice that uses ionising radiation, is required or advised to keep a number of records relating to that activity.

risk analysis and installation plans **

inventory of radiation equipment *

installation modification and maintenance records **

performance data and inspection reports **

referrers and practitioners **

persons authorised to maintain and to use radiation equipment *

qualifications and training of users *

names and contact details of RPA, RPS, MPE *

patients' names *

"pregnancy forms" **

indications for x-ray studies **

x-ray requests and authorisations **

findings from x-ray examinations *

exposure details **

quality assurance records **

records of investigations of actual or suspected radiation accidents *

* statutory records

** advisory - provides evidence of compliance with a statutory requirement.

It will be clear from the following that it is advisable for an employer to keep an "IRR" and an "IRMER" file up to date.

4.4.2 Building and equipment records

IRR 8,9 Chiropractic x-ray facilities should be constructed and laid out so that no person (other than a patient) is likely to receive a radiation dose in excess of the limit for "other persons", 1 mSv/yr. This is achieved by prior risk analysis, layout design, and incorporation of protective material as necessary in the structure. Few of the protective measures are visible in the finished room, and the dose outside the protected area is difficult to measure. Design documentation, builders' certificates, and critical examination reports, are needed as evidence of compliance with the statutory requirement.

IRMER 10 The employer must maintain an up-to-date inventory of radiation equipment, keep it on site, and make it available to the appropriate authorities on request. The first inventory will usually be compiled by the installer or the RPA carrying out the critical examination, and should list the manufacturer, model number, serial number, year of manufacture, and year of installation, for all those items that generate, control and restrict the x-ray beam.

In practice it is useful to record the serial numbers of all mechanical and electrical (M&E) parts in the inventory: retrospective checks or modifications are notified from time to time by the Medicines and Healthcare Products Regulatory Agency and are more often concerned with M&E faults than with radiation protection.

The supplier should provide a separate box or cupboard to house all the "accompanying documents": the circuit and mechanical drawings and instructions necessary to install, deinstall, maintain and repair the equipment. Modification records should be kept with the accompanying documents, but the invoices for routine maintenance and repair work should be considered as part of the employer's "proof of diligence" and kept with the health and safety records. The operator's instruction book must be accessible to the operator.

IRR 11, 31 IRMER 4 Radiation equipment must be properly maintained, subject to quality assurance, and used in a context that allows the calculation of patient dose. The RPA should periodically assess the adequacy of maintenance, review the QA programme, and collect data for dose calculation. His inspection reports are therefore valuable evidence of compliance, and source documents for patient dose calculation, and should be filed with the health and safety records.

4.4.3 Staff and other personnel records

IRMER 4 The employer must authorise the "practitioners", i.e. those persons within the practice who may justify and authorise x-ray exposures. These will usually be the chiropractors who satisfy IR(ME)R training requirements, though in a shared practice it may be possible for a doctor or a physiotherapist with adequate training to act as a practitioner.

It is advisable for the local rules to state who is permitted to use the x-ray equipment. All the current clinical operators must be named, though "and others specifically authorised from time to time by the employer" allows maintenance engineers, RPAs, etc., to operate the equipment with specific permission.

Chiropractor interns and students may be listed as operators provided they work under the supervision of a qualified chiropractor or radiographer (**IRMER 11**).

There must be a record in the IRMER file of the qualifications, qualification date, and post-qualification training, of every practitioner and operator.

IRMER 5, 6 "Unreported film" requests from outside the employer's clinic should be considered in the same way as requests for "medico-legal" exposures, that is to say: the practitioner must be certain that each image will be reported and acted upon, that there is a probable net benefit to the patient from the radiation exposure, and that there are sound medical grounds for requesting an x-ray image. This is best achieved by written contracts with all external referrers, in which the referrer undertakes to support each request with an adequate clinical history and to ensure that the films will be read by a qualified person. These contracts are essential records.

IRR 14 The radiation protection adviser must be suitably qualified and experienced. He should supply the employer with adequate certification, and appropriate means of making contact. It is most improbable that any emergency can arise in chiropractic radiography that requires the immediate advice of an RPA on site, but the employer should keep the RPA's telephone and fax numbers to hand - preferably written into the local rules

IRR 17 The radiation protection supervisor in a chiropractic clinic is unlikely to need specialist training beyond the basic qualification in chiropractic radiography, but must be nominated as the person in day-to-day charge in the local rules and on his staff record, must be given the employer's authority to run the x-ray facility in a safe and efficient manner, and must be named in the local rules.

IRMER 9 In the unlikely event that an employer appoints a medical physics expert other than the RPA, his duties and authority must be set out in an explicit contract, and the means by which staff can consult him from day to day must be made clear to all practitioners and operators. The RPA, MPE's and RPS contracts are essential clinic records.

4.4.4 Radiological findings

IRMER 4(1) Schedule 1 requires the employer to have written procedures "for the carrying out and recording of an evaluation for each medical exposure including, where appropriate, factors relevant to patient dose". In practice the latter duty can be discharged by maintaining a daybook that records all the exposure factors against each patient's name, but the first requirement implies that every exposure must be "reported" and the report must be maintained as a patient record.

Since the many chiropractic x-ray examinations are undertaken to eliminate contraindications or confounding pathology, a significant number of reports will be substantially negative. The medical shorthand NAD (Nothing Abnormal Detected) is unlikely to be true if the patient meets one of the standard criteria for radiological examination, but NVC (No Visible Contraindication to manipulative treatment) is a defensible entry if the visible pathology does not significantly alter the planned treatment.

It is advisable to note whether any positive findings of unexpected pathology or contraindication to manipulation have been reported orally to the patient, and to keep copies of any written reports that are sent outside the practice.

If images are reported or re-reported off-site, that activity should be defined

in a contract which names the reporter and the scope of advice he is required to give, and the top copy reports should be filed as patient records.

There is no statutory requirement to keep x-ray films beyond their immediate clinical usefulness, provided the reports are adequate and properly maintained. Most private medical practices give original films or copy CDs to the patient for safe keeping. However the General Chiropractic Council Code of Practice currently requires chiropractors to retain original images, for reasons of its own.

4.5 Quality Assurance (QA) and Quality Control (QC)

4.5.1 X-ray generator

IRR32 (3) The employer must provide a suitable QA programme for the x-ray equipment to ensure that it continues to restrict exposure as required for the clinical purpose.

Very little can be done to predict the performance of an x-ray generator. Delivered kV and mAs do not generally "drift" but are subject to (very rare) catastrophic change if a critical component fails. This may be foreshadowed by a period of inconsistent operation, which will be apparent in the clinical images. Any apparent inconsistency in kV (image contrast and density departs from expectation) or mAs (image density varies but contrast remains correct) must be noted in the exposure log and investigated immediately. Any variation that is not apparent in the clinical image is of no significance.

The x-ray/light beam alignment must be checked regularly if the edges of the field are not clearly visible on the films. It is sufficient to radiograph a wire framework (paper clips are suitable: 50 - 55 kV 2 mAs) and realign the light

beam edges to the x-ray image, within 0.5% of the focus-film distance (7.5 mm at 150 cm ffd).

IRR 32 (4) The maintenance engineer must test the equipment after any repair or service work to demonstrate that it has been restored to its intended performance. If the performance has altered, the RPA must be consulted before the equipment is returned to clinical service. It is particularly important to check, if the collimator has been dismantled from the tube head, that the original filtration has been restored.

4.5.2 Image processing QA

IRMER 4 (2) (b) The employer must establish a quality assurance programme.

The most important component of the imaging chain, from the point of view of a QA programme, is the film processor or CR scanner.

In the case of a manual processor, daily temperature checks and monthly processing of a pre-exposed test film will suffice to assure consistency. The replenishment rates of an automatic processor should be kept under review, and a pre-exposed test film should be processed every week or fortnight and compared with the reference film. Any deviation from the required chemical temperature, replenishment rate, or appearance of the test film, must be investigated and corrected.

Routine cleaning and chemical replacement, according to the instructions of the processor or chemical manufacturer, are essential elements of quality assurance, as are the immediate investigation and repair of any mechanical or electrical problems (grating gears, wet film).

Quality assurance in digital radiography similarly concentrates on the performance of the scanner and image processing system.

In the case of CR and DR, the critical parameters are detector dose indication (DDI), uniformity, and spatial resolution. It is convenient and generally recommended to check each parameter every 3 months.

Each manufacturer has a different definition, symbol and recommended procedure for measuring DDI, but the underlying principles are the same: irradiate the entire cassette evenly with a very small dose, scan the plate under a standard sensitivity and display algorithm, note the displayed DDI value, compare with the manufacturer's specification, and scrutinise the image for uniformity and absence of artefacts. The usual "low dose" condition is provided by placing a 1 mm copper filter in the x-ray beam and using exposure factors of the order of 80 kV, 1 mAs. If a copper filter is not available, a pack of computer paper and factors of 50 kV, 2 mAs will provide a repeatable exposure condition for a constancy test.

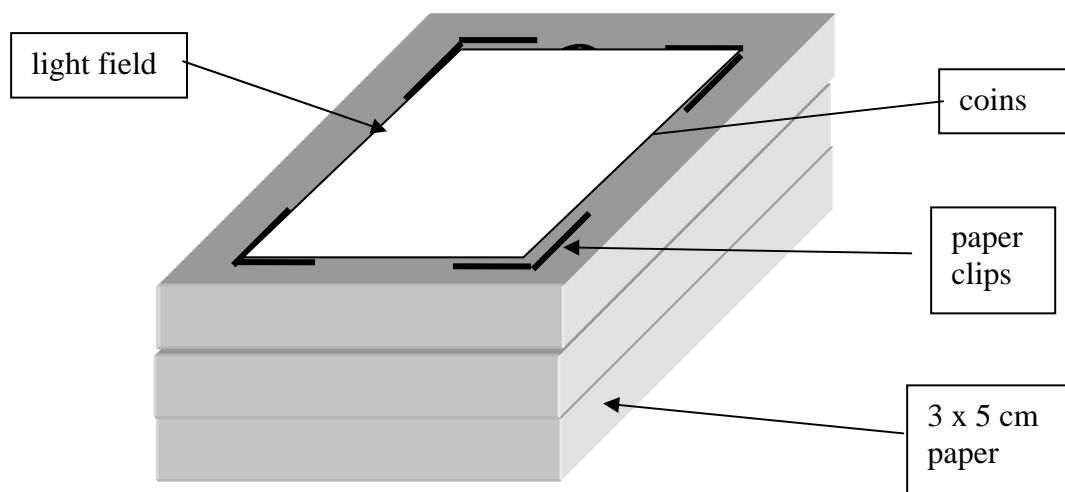
Limiting spatial resolution should be tested with about 50 kV, 2 mAs exposure, with no copper or paper filtration in the beam. If a calibrated test object is not available for absolute measurement, an old "memory stick" or similar printed circuit with fine copper tracks may be used as a constancy test. Place the test object on the cassette or image receptor and radiograph it with no grid present. Do not use the edge enhancement algorithm.

Every CR plate should be tested every 3 months.

Low-contrast object resolution tests are normal in hospital use, but it is unusual for a chiropractic clinic to have the requisite laser hardcopy printer, or constant and optimised display conditions. However it is important to

check the ambient light levels from time to time, and to check the display light output at the routine service intervals.

It is worthwhile constructing a simple "one shot" test object. 3 reams of computer paper, four paper clips and a few copper coins can be radiographed monthly using the same exposure factors. Compare the images (using the same processing algorithm) with the baseline image obtained when the equipment was first set up or after a manufacturer's service calibration.



It should be possible to discern detail in the coins, and the coincidence of the x-ray beam with the light beam can be assessed by collimating to the L-shaped wire markers.

4.5.2 Quality control

Every clinical image must be viewed critically, as if it had been purchased from an outside agency. Any deviation from the expected quality must be noted in the exposure log book, which must be reviewed periodically to determine whether the exposure factors or standard radiographic techniques should be modified. Obvious problems (dirty, scratched, fogged, underdeveloped films, cracked CR plates, etc.) must be investigated and

corrected before another film is exposed.

4.5.3 Quality records

The exposure log book should record the dates and details of any changes in practice (radiographic technique, developer temperature, algorithm, etc.) and the service engineer's repair dockets should be kept as evidence of any major action initiated in response to or anticipation of quality problems.

5. Bone densitometry

X-ray attenuation is a function of the density and atomic number of the attenuating material, and energy of the x-ray beam. If the beam energy is varied, the difference between two images is attributable to the absolute value of the attenuation of each part of the object.

A modern dual-energy x-ray absorption (DEXA) scanner uses a fan-beam of x-rays generated at about 100 kV and 140 kV, and a linear array of photoreceptors, to generate two image data streams. The sum of the data streams is displayed as a planar image, from which the operator selects a region of interest (roi) - usually one or more lumbar vertebrae but occasionally part of the hip, forearm or even a finger. The difference between the data streams in the roi is used to calculate bone density.

Patient dose is very low - typically less than 15 microsievert for a lumbar scan and negligible effective dose for a forearm - and the results from a properly calibrated scan are indicative if not definitive of bone demineralisation. The definitive test is generally held to be a quantitative CT study of the pelvis, with significantly greater dose.

The image from a DEXA scanner is not intended to be diagnostic or geometrically accurate, but it will show gross deformities and large fractures, and such findings may be confidently presented along with the actual densitometry results.

In view of the very low radiation dose, it is reasonable to carry out follow-up DEXA scans to review the effect of antiresorptive medication or other treatment. It is certainly advisable to refer a patient for a DEXA scan (or conduct one in-house) if history or x-ray examination suggests that the patient may not sustain the rigours of energetic manipulation.

Even though the effective radiation dose from a DEXA scan is minute and the risk to staff is too small to quantify, it is necessary to maintain adequate and specific training records for all those who operate bone densitometers or interpret the results, and the IR(ME)R requirements for referral criteria, protocols, justification and optimisation apply exactly as for a radiographic examination. The National Osteoporosis Society www.nos.org.uk runs a comprehensive training and certification scheme.

6. Other imaging modalities

IR(ME)R 6(2) (d) The practitioner is required, in the process of justification, to take into account "the efficacy, benefits and risk of available alternative techniques having the same objective but involving no or less exposure to ionising radiation." It is beyond the scope of this document to deal with the detailed practicalities of all the imaging techniques applicable to chiropractic but the characteristics of the most common modalities can usefully be compared with plain x-radiography.

A summary table of the characteristics of common imaging modalities follows a brief discussion here.

6.1 Musculoskeletal ultrasound

High frequency sound waves can propagate through human tissues and are reflected from discontinuities in the elastic properties of the tissues. The time taken for the reflected wave to return to its source indicates the distance from the source to the reflection. The combination of transit time and reflected intensity of a pulse of ultrasound can be assembled into an image of the tissues.

The ultrasound probe effectively images a fan-shaped anatomical "slice" image in real time. If the reflecting target moves, the frequency of the reflected pulse is altered by the Doppler Effect, so blood flow or tendon movement can be assessed, and in principle a number of "slice" images can be stacked to produce a 3-dimensional representation of anatomy and motion.

Ultrasound imaging equipment is generally lightweight, compact, fairly robust, and considerably cheaper than x-ray, and as it generates no ionising radiation or other significant hazard there are no statutory restrictions on its use. It is particularly valuable for domiciliary and sports stadium assessment of soft tissue damage and inflammation.

The availability of an ultrasound image is very dependent on operator skill in selecting an appropriate window between bony structures (which reflect ultrasound too strongly to permit imaging of underlying anatomy) and avoiding voids (ultrasound is not transmitted through air or bowel gas).

Since the reference origin for image reconstruction is the transducer itself, it is not easy to relate the image to gross posture - a hand-held transducer gives no indication of "vertical" and the field of view (fov) may not include landmark structures.

6.2 Magnetic resonance imaging (MRI)

Hydrogen nuclei in the body behave as spinning magnetic gyroscopes. They tend to align with a strong external magnetic field. Excitation by a pulse of radio waves at the resonant frequency forces them to precess around the external field vector. The resultant rotating magnetic field can induce a detectable current in a receiver coil. The nuclei relax back towards the primary field direction and this resonance signal gradually decays.

Different tissues have different concentrations of hydrogen, in different chemical combinations, and therefore exhibit different rates of relaxation. It is thus possible to distinguish between, say, fat, water, muscle, cartilage and grey/white brain matter by observing the change of the emitted signal as the protons relax. This provides the opportunity for imaging soft tissue in the presence of very large amounts of bone, and thus visualising intervertebral discs and the spinal cord. Soft tumours and nerve compression are clearly demonstrated and differentiated and MRI can be considered complementary to x-ray or CT.

The location from which the MRI signal is derived is determined by adding "gradient" magnetic fields to the primary field. In most MRI systems the gradient coils, which carry a very large and rapidly varying current, generate a loud noise close to the patient, who is enclosed in a narrow tube which carries the primary magnet. The experience is at best unpleasant and can be frightening, with up to 10% of patients failing to complete their first examination and perhaps 20% refusing follow-up tests even when seriously ill. More importantly, the primary field is strong enough to dislodge shrapnel, metal dust, aneurysm clips and other surgical metalwork, and the oscillating gradient fields can generate dangerous currents in pacemaker wires or even cause local burning if the patient has used a metallic cosmetic.

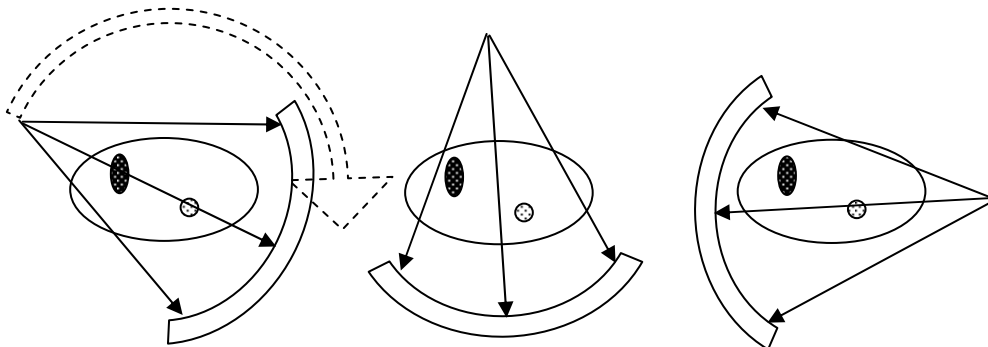
Some 50% of symptomatic patients show no radiological signs associated with their lower back pain when imaged by conventional MRI. This is not a shortcoming of the MRI process, but of engineering: it is difficult to build a superconducting magnet that can accommodate a standing patient, and the recumbent posture generally imposes near-normal geometry on the spine and discs.

Fortunately, erect MRI is now becoming available in the UK and the heavy iron-cored electromagnet required for this procedure is both "open" (the patient walks into the magnet and faces the operator directly throughout the procedure) and very quiet (the gradient coils are fixed to a rigid 150-tonne structure). With the patient standing, seated or supported in the posture that actually causes pain, the demonstration of disc and spinal cord pathology, including transient effects due to mobile lyses, approaches 100% and very few patients are unable or unwilling to tolerate the procedure.

At the time of writing there was only one commercially-accessible upright MRI scanner in the UK, and the procedure was expensive (about 15 times the cost of a chiropractic x-ray examination). Whilst MRI is advocated as the spinal imaging modality of choice in an ideal world, the poor yield of recumbent MRI, the cost of upright scanning, the inconvenience of travelling to a suitable centre, and the need to wait in pain for an appointment, generally make in-house x-ray the preferred examination for chiropractic. Geometric accuracy is certainly better than ultrasound but MRI bone outlines are rarely suitable for precise measurement.

6.3 Computed tomography (CT)

An x-ray tube and collimator generates a narrow, fan-shaped beam which passes through the patient to an arc array of detectors. The assembly is rotated around the patient:



Here the central ray passes first through two "bony features", then through "soft tissue" and finally through just one of the bony features as the gantry rotates. Given several sets of data showing the angular position of the source and detector assembly, and the distribution of received x-ray intensity, it is intuitively possible to deconvolute the overlapping attenuations and reconstruct the position and x-ray attenuation of each element of the patient, and thus to generate an image of a "slice" through the patient. A 3-dimensional image may be synthesised by stacking several overlapping slices together.

CT spatial resolution is exquisite, and the technique is ideal for examining anatomy inside dense bony structures, especially the skull and spine. Soft tissue differentiation is less impressive than with MRI as the object contrast is relatively poor, but CT is definitive for vertebral fractures and dense tumours.

Since the image is effectively reconstructed from a large number of individual radiographs, the radiation dose to the patient is large compared with a radiographic examination of the same area. More significantly, whilst a radiographic x-ray beam is mostly absorbed in the skin and outer muscles, a CT beam is necessarily of higher average energy and filtration than a plain radiography beam and thus the ratio of the effective dose to internal organs to the entrance surface dose, is greater. Pregnancy should be considered a contraindication to anything other than a cranial, cervical or distal limb study.

All CT systems are designed for imaging the recumbent patient, so whilst geometric accuracy is excellent, a CT scan is unlikely to demonstrate biomechanics of chiropractic interest. From the chiropractic point of view CT should be regarded as a diagnostic rather than an assessment tool but its timely application particularly in the case of suspected vertebral fracture or bone disease or malformation may be crucial. The capital and operating cost of CT is little more than a sophisticated plain x-ray system and the high utilisation and ready availability of CT scanning makes it an important modality for radiodiagnostic, orthopaedic or neurosurgical consultation.

6.4. Fluoroscopy

Note Practical training in fluoroscopy is not normally included in the undergraduate syllabus of chiropractic radiology. Any chiropractor wishing to undertake fluoroscopic examinations is strongly advised to contact a professional association, an educational establishment, or the College of

Chiropractors, to establish a written consensus on the justification of such investigations and to obtain a certificate of appropriate training.

6.4.1 Statutory requirements

IRMER 7 (9) (a) "The operator shall ensure that examinations without devices to control the dose rate shall be limited to justified circumstances." Subject to judicial interpretation, this is probably intended to advocate the use of automatic exposure control (AEC) circuits which vary fluoroscopic kV and mA according to the brightness and contrast of the image. In practice it may be necessary to disable the AEC system when studying a moving, high contrast object such as a cervical spine, but the written protocol for doing so in a chiropractic clinic should be established in advance.

IRMER 7 (9) (b) Direct viewing of a fluorescent screen is prohibited: an image intensifier or equivalent (e.g. direct-to-digital television system) must be used.

IRR 16 It is almost invariably necessary to designate a fluoroscopy suite as a controlled or supervised area as special procedures are necessary to minimise the dose received by staff. The RPA must be consulted on the local rules and protocols required for compliance with IRR.

IRR 8 (2), 9, 10 Personal protective equipment (usually a lead-rubber apron) will be needed to ensure that the dose to the operator and any other person in a fluoroscopic x-ray room is ALARP. This must be correctly designed, worn, stored, maintained and inspected, and the inspection and maintenance records should be retained. The Personal Protective Equipment (EC Directive) Regulations 1992 apply: the RPA must be consulted on compliance.

IRR20 Subject to the RPA's assessment, it is unlikely that any employee

involved in chiropractic fluoroscopy will need to be designated as a classified person. However it is generally necessary to monitor the personal dose of anyone who works in a fluoroscopic suite to ensure that they do not need to be designated.

IRR21 It is advisable to obtain personal dose monitoring badges from an Approved Dosimetry Laboratory that can maintain the necessary records. The RPA must be consulted.

There are two possible approaches to personal dose monitoring in chiropractic fluoroscopy: either the badge is worn under the lead apron, and hence estimates effective dose to the trunk and gonads, or it is worn on the upper arm or collar, and thus estimates the dose received by the thyroid, eyes, and exposed active bone marrow. In practice, the lead apron tends to be generously specified and the "trunk" badge does not record a significant dose even if the arms and head are heavily exposed to scattered radiation. The RPA must be consulted on the optimum placement and interpretation of monitoring badges.

IRR 7 A room designed for conventional chiropractic radiography may not be suitable for fluoroscopy, and *vice versa*. The RPA must be consulted, and must undertake a separate risk assessment, if any such change of use is contemplated.

6.4.2 Protocols for chiropractic fluoroscopy

The use of fluoroscopy to determine the optimum timing or position of a radiographic exposure is not appropriate in chiropractic. Fluoroscopic examination should only be used to investigate unstable or pathological movement, or complaints related to pain during motion. With this in mind, it

is essential that the entire examination be recorded on videotape, which is then labelled and treated as a permanent record in the same way as a radiograph.

The installing x-ray engineer should interlock the exposure control to the video recorder and the acceptance test should include a confirmation that all fluoroscopic exposures will be recorded.

The RPA or MPE must be consulted with regard to estimating patient dose from the video recording, and a fluoroscopic exposure log must be established to record the parameters necessary for that estimation.

Written clinical procedures must be established and the patient must be rehearsed for each investigation to explain the procedure and minimise unnecessary exposure.

6.4.3 Quality assurance for fluoroscopy

The gain of the image intensifier tube and television system should be checked at least annually. A "replacement level" must be established (with the MPE's advice) and adhered to.

Fluoroscopic image quality is most commonly degraded by mechanical shock which disturbs the optical focus of the t.v. camera system. The limiting spatial resolution must be checked at least annually.

Image intensifiers and television camera tubes gradually lose contrast. This is of less importance in chiropractic studies than in general radiology but the limiting contrast/noise ratio or the system contrast/detail curve should be investigated at least every three years.

The performance of automatic exposure controls must be checked every 2 - 3 months. As a minimum check, the system should respond sharply and correctly to a step change from 1 mm to 2 mm copper phantom placed in the beam.

"Warped" images must be investigated as soon as the distortion is noticed.

The above notes represent a minimum set of routine checks. The MPE must advise, in consultation with the maintenance engineer, on a full QA programme. It is unlikely that a chiropractic clinic will have the resources to carry out more than the minimum without external assistance.

In hospital use, it is unusual for a simple fluoroscopic system to perform satisfactorily for more than 5 - 8 years. Under chiropractic conditions of use it is probable that the vacuum components will degrade to replacement level in 8 - 10 years.

6.5 Radionuclide imaging ("bone scan", "nuclear medicine scan")

Radiolabelled pharmaceuticals are injected (or occasionally ingested) and are distributed around the body according to the activity and physiology of each organ or lesion. After a few minutes during which the pharmaceutical is taken up from the blood pool by the target organs, the patient lies or occasionally sits close to a large scintillator which converts the emitted radiation into light that is measured by an array of photomultipliers and thence converted into a planar image of the distribution of the pharmaceutical.

With an appropriate choice of pharmaceutical and radionuclide, it is possible to identify active nodes such as focal bone changes including recent fractures, or primary and secondary tumours. The process is inherently quantitative so the crude anatomical delineation of a nuclear medicine investigation is accompanied by very precise physiological measurement and fairly specific biochemical differentiation.

Better spatial resolution can be achieved by using a tomographic (SPECT) technique and the combined use of positron-emitting radionuclides and CT gives both spatial and metabolic information. This is unlikely to be of consequence in chiropractic evaluation but an endocrinology workup may usefully involve PET-CT.

The capital cost of a radionuclide imaging suite is high but a single scan is relatively cheap. Radiation dose is significant (generally in the region 1 - 10 mSv) to the patient and possibly her family - pregnancy and breast feeding must be taken into particularly careful consideration.

6.6 The relevance of prior studies

It is quite likely that a chiropractic patient will present with a history of other investigations. **IR(ME)R 6 (4)** requires the practitioner to "take account of any data supplied by the referrerand..... consider such data in order to avoid unnecessary exposure". Such data should include existing, recent and relevant images. Clearly a chiropractor acting as referrer should ask the patient for any reports and preferably actual images of recent investigations carried out elsewhere. It is very common for a chiropractic interpretation of a "hospital" image to add significantly to the patient's diagnosis and treatment.

In considering prior studies it must be remembered that a standing x-ray examination will generally demonstrate spinal geometry and other biomechanics better than any other modality, and that the additional radiation dose incurred from one or two radiographs may be insignificant compared with a previous CT or bone scan. It is also important to consider the timing of any prior study (has there been any intervening trauma or degeneration?) and the actual region imaged ("textbook" lumbar spine films, even erect, do not show hip joints or pelvic tilt.)

New facility checklist

Lease terms or freehold covenants - agreement for necessary building works

Space for x-ray equipment and darkroom

Open x-ray records file, including IRR99 and IR(ME)R files

Sketch or architect's plans of building showing existing materials

Power supply capacity / supply company restrictions / new cable costs

Waste disposal

Budget, finance and timetable

Contact Radiation Protection Adviser

Invite suppliers' layout proposals

Submit preferred proposal to RPA

 risk analysis and preferred layout

Contracts for pre-installation

 building and finishing

 x-ray equipment

 processor and darkroom

 film, chemicals and waste disposal

Specialist contractors (pre-installation electrics, shielding)

Building works schedule

Notify Health & Safety Executive at least 28 days before completion date

Film filing system and equipment

Establish operational quality system

 log book

 patient forms

Operator training or retraining

Appoint and instruct RPS

Installation

RPA's critical examination and acceptance testing

Establish exposure chart

Field Operations Directorate
Health & Safety Executive
Phoenix House
23 - 25 Cantelupe Road
East Grinstead
West Sussex RH19 3BE

Ionising Radiations Regulations 1999: Notification under Regulation 6 and Schedule 2

a. Name and address of Employer

Tel: fax: email:

b. Address of premises where work is to be undertaken *As above*

Radiation Employer at this site:

c. Nature of business *chiropractic radiography*

d. Source of radiation *fixed chiropractic x-ray generator*

e. Mobile sources *none*

f. Anticipated date of commencement of work:

Please note that I have consulted and retained:

as Radiation Protection Adviser.

Scope of consultation: *Regulation 7
Regulation 12
Regulation 13 Schedule 5
Regulation 32
Medical Exposure Regulations*

Signed

Anytown Chiropractic Clinic

Model Local Rules

1. For the purposes of the Ionising Radiations Regulations, the Radiation Employer and the Radiation Protection Supervisor (RPS) is **Dr J Smith**. It is the duty of the RPS to enforce these Rules and report incidents or non-compliances' with the Rules or the Regulations as appropriate. The dose investigation limit is 0.75 mSv/year
2. The statutory requirements of the Ionising Radiations Regulations and Ionising Radiation (Medical Exposure) Regulations must be observed.
3. Only the following persons are authorised to use the x-ray equipment
..... and others specifically authorised from time to time by one of the above.
- 4a. The x-ray room, apart from the area immediately behind the protective screen, may only be occupied by one patient and *if absolutely necessary* an escort (who should not be an employee), when the x-ray equipment is in a condition to emit radiation. The entrance door must be locked during any exposure. The name of the patient and any escort must be recorded in the exposure log book before the patient leaves the x-ray room - see 6e.
- 4b. The operator must ensure that the following areas are unoccupied before any exposure is made.....
5. Any incident resulting in an unintentionally large exposure of any person to radiation must be reported promptly to the Radiation Protection Adviser (RPA) **W Brown, tel: 1234 5678**.
- 6a. No patient may be exposed to x-radiation until the patient file records the justification (i.e. clinical indication) for that exposure
- 6b. Every film must be labelled with the patient's name and the date.
- 6c. A report must be made, in the patient's file, for every exposure.
- 6d. Requests for "unreported" films may only be accepted from persons approved by the Employer and listed in the Referrers file.
- 6e. The minimum dose necessary for diagnosis shall be used (the exposure chart provides a guide) and the beam shall be collimated to expose only the region of interest. Gonad protectors should be used where possible.

- 6f. Each exposure must be logged in the daybook against the patient's name, with sufficient detail (kV, mAs, f.f.d., region of interest) to allow the patient's dose to be estimated. The operator must initial the daybook.
7. Abdominal and pelvic studies should not be carried out on anyone who is or may be pregnant. The "28 day rule" may be used if pregnancy cannot be excluded. Accidental exposure of a foetus must be reported promptly to the RPA with all exposure details (kV, mAs, ffd, number of exposures).
8. If the generator fails to terminate an x-ray exposure
- SWITCH OFF AT THE CONTROL DESK AND THE ISOLATOR
 - HELP THE PATIENT TO LEAVE THE ROOM IMMEDIATELY
 - CLOSE THE DOOR
 - EVACUATE THE X-RAY ROOM FOR AT LEAST ONE HOUR (possible explosion hazard from an overheated tube)
 - FIX A "DO NOT USE" NOTICE TO THE CONTROL DESK
 - INFORM THE RPA AND THE SERVICE ENGINEER AS SOON AS POSSIBLE
 - WRITE DOWN ANY INFORMATION (EXPOSURE FACTORS, ETC) THAT WILL HELP CALCULATE THE PROBABLE PATIENT DOSE AND ESTABLISH THE CAUSE OF THE FAULT
9. Darkroom procedure is the key to minimising radiographic dose.

Unexposed films should not be left loaded in cassettes longer than absolutely necessary, and preferably not over a weekend or holiday. Films must be developed as soon as possible (and in any case within 24 hours) after exposure. Out-of-date material should not be used. If in doubt, consult the RPS.

Processor maintenance and quality assurance procedures are listed in the TQA file and are the responsibility of the RPS. In the absence of the RPS, new chemicals must be made up according to the manufacturer's instructions. The developer temperature must be within the manufacturer's recommended limits.

The processor must be warmed up for each session according to the manufacturer's instructions, there must be enough material in the replenishment tanks for the session, and sufficient "cleanup" films must be passed through the processor before any clinical films are processed.

Any deterioration of image quality, or the appearance of persistent light spots on the images, must be recorded in the exposure log book, then reported to and investigated by the RPS.

Ensure the door is bolted when the darkroom is in use, and left open for ventilation whenever possible

10. The RPS must review the exposure log book at least monthly, and consider whether, in the light of any changes in exposure factors or comments, there has been any change in the performance of the equipment or the darkroom. If in doubt, consult the RPA.

For CR imaging, substitute

9. Image processing procedure is the key to minimising radiographic dose.

Re-erase any plates that have not been used for a month.

Process and erase exposed plates immediately after exposure and return them to the bottom of the stack, to ensure that plates are used in rotation.

Save all images, including "failed" exposures - these may prove diagnostic of equipment problems.

Report any persistent artefacts, or failure to generate a satisfactory image with standard exposure factors, immediately to the RPS. If the RPS is unable to resolve the problem, inform the service engineer and the RPA.

10. The RPS must review the exposure log book at least monthly, and consider whether, in the light of any changes in exposure factors or comments, there has been any change in the performance of the x-ray generator or imaging system. If in doubt, consult the RPA.

Name.....
Date.....
Ref. no.....

I am not pregnant

I may be pregnant. I have had the risks of x-radiation in pregnancy explained to me, and the reason why an x-ray examination is necessary for my treatment, and I hereby give consent to be x-rayed as requested below

Signed..... dated.....

I have made a clinical examination of this patient and now request an x-ray examination. The patient meets the following criterion/a:

50+ | Tra | Neu | UWL | Art | DAA | Mal | Ste | Pyr | Sco | Sur | FTI | EBF | Pos | LEP

Clinical indications.....

Clinical summary.....

Signed.....chiropractor (as referrer) Date.....

Please take the following x-ray films of this patient

APCx | LatCx | OblCx | APOM | Shldr | PATH | LatTh | OblTh | PALx | LatLx
R/L R/L R/L

Other.....

Notes.....

Authorised by (sign)..... (as practitioner)

Date.....

Findings from the above examination:

Signed.....chiropractor

Date.....

Key to referral criteria:

50+ age 50 or over

Tra trauma

Neu neurological deficit

UWL unexplained weight loss

Art inflammatory arthropathy

DAA drug or alcohol abuse

Mal malignancy

Ste history of use of steroids

Pyr pyrexia

Sco investigation of scoliosis

Sur surgery in region of interest

FTI failed to improve with conservative treatment

EBF equivocal biomechanical findings

Pos investigation of extreme postural anomaly

LEP clinical examination limited by pain

BERT, the Background Equivalent Radiation Time, is the creation of Professor J R Cameron of the University of Wisconsin. It relates the effective dose from diagnostic radiation sources to the time required to obtain the same dose from natural background (cosmic radiation, radon, terrestrial gamma radiation, and the body's own radioactivity)

Cameron's tables relate medical exposures to the mean effective dose from natural background radiation in the USA, approximately 3 mSv/yr. The foetal dose estimate given here is derived from calculations of unintentional foetal dose actually delivered by chiropractors in the United Kingdom, and the effective dose for a cervical spine study is derived from UK chiropractic records, but for consistency they are related to the US background dose rate.

X-ray study	Effective dose (mSv)	BERT
Dental, intraoral	0.06	1 week
Cervical spine	0.1	2 weeks
Chest	0.08	10 days
Thoracic spine	1.5	6 months
Lumbar spine	3	1 year
Upper GI tract	4.5	1.5 years
Lower GI tract	6	2 years
Fetal dose from chiropractic lumbar series	1	4 months

Adapted from Cameron J R, Medical Physics World 15 (2) (1999) p 20.

Coincidentally, the statutory dose limit for the foetus of a woman who works with ionising radiation has been set at 1 mSv (**IRR 11**), there being no evidence of attributable harm at this level of exposure.

7.6.1 IRMER: SCHEDULE 1 Regulation 4(1)

Employer's Procedures

The written procedures for medical exposures shall include

- (a) procedures to identify correctly the individual to be exposed to ionising radiation;
- (b) procedures to identify individuals entitled to act as referrer or practitioner or operator;
- (c) procedures to be observed in the case of medico-legal exposures;
- (d) procedures for making enquiries of females of childbearing age to establish whether the individual is or may be pregnant or breastfeeding;
- (e) procedures to ensure that quality assurance programmes are followed;
- (f) procedures for the assessment of patient dose and administered activity;
- (g) procedures for the use of diagnostic reference levels established by the employer for radiodiagnostic examinations falling within regulation 3(a), (b), (c) and (e), specifying that these are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied;
- (h) procedures for determining whether the practitioner or operator is required to effect one or more of the matters set out in regulation 7(4) including criteria on how to effect those matters and in particular procedures for the use of dose constraints established by the employer for biomedical and medical research programmes falling within regulation 3(d) where no direct medical benefit for the individual is expected from the exposure;
- (i) procedures for the giving of information and written instructions as referred to in regulation 7(5);
- (j) procedures for the carrying out and recording of an evaluation for each medical exposure including, where appropriate, factors relevant to patient dose;
- (k) procedures to ensure that the probability and magnitude of accidental or unintended doses to patients from radiological practices are reduced so far as reasonably practicable."

7.6.2 Using a Quality System

These notes set out a model quality system that addresses all the requirements of Schedule 1, and can be adapted to suit any chiropractic clinic.

Schedule 1 extends beyond mere QA and QC of the equipment ("technical QA") and is in fact a subset of a full ISO9002 Standard Quality System that can be applied to any department of clinical radiology. The phraseology of the Schedule reflects the technical terms used in that Standard.

Item (a) has two possible and relevant interpretations

The name of each patient must be recorded and accurately associated with all the exposure details and products (radiographs and reports) for that patient
or

The authorisation for exposing any patient must be recorded against the patient's name.

"Medico-legal exposures", item (c), can best be interpreted as "films requested 'unreported', from outside the practice". Since every exposure must be justified, it is necessary to assign liability for that justification if the in-house practitioner or operator is not in a position to justify it himself. The employer should therefore negotiate and record effective contracts which name outside referrers who can justify an exposure in terms of probable benefit to the patient and authorise it, i.e. act as practitioner.

Such contracts can name other chiropractors, osteopaths, doctors, podiatrists, or physiotherapists, who have sufficient training.

If patients are referred by an insurance company or a solicitor, the employer must be sure that the referrer will pass the film to a doctor for reporting.

Police, immigration, or customs officers must refer through a doctor.

Clinical audit, as required by Regulation 8, is addressed here as part of the quality assurance procedures required by paragraph (e) of Schedule 1.

Other parts of the Schedule are self-explanatory. The attached model system addresses them all in turn.

7.6.3 Model Quality System

Lead Document for Chiropractic Clinic

The Employer, for the purposes of the Ionising Radiations Regulations, is.....

It is the Employer's responsibility to ensure that this Quality System is kept up to date and implemented.

The Radiation Protection Supervisor for this site is.....

The RPS is responsible for day-to-day maintenance of quality and is authorised to act for the Employer.

The Radiation Protection Adviser is.....tel.....

The RPA is retained to advise on all matters relating to the radiation exposure of patients, staff or third parties and on quality assurance. He can be contacted immediately in case of an actual or suspected accident, and through the RPS for non-urgent advice.

All practitioners and operators must conform to the following procedures:

- (a) The patient's notes must record the reason for requesting x-rays, and the signature of the authorising practitioner. If the patient is handed on from the practitioner to another person acting as operator, the notes must include a written request specifying the parts to be radiographed. Use the "tick lists" or write in a clinical indication for the examination and a specific request for each film. The record must be filled in before the patient proceeds to the x-ray room.

Before any patient is radiographed, ensure that he/she has a legible i.d. slip bearing his/her name, today's date, and his/her patient reference number.

Before he/she leaves the x-ray room, ensure that the i.d. slip has been copied onto every film taken.

Complete the exposure log for every exposure, before taking the next. Initial the exposure log before you leave the x-ray suite.

- (b) The list of persons authorised to use the x-ray equipment or to carry out maintenance operations on the x-ray or processing equipment is attached to the Local Rules.

Their records of training and qualifications are kept in the "Staff Training" file.

No-one else may x-ray a patient or interfere with the x-ray or processing equipment, or handle unprocessed x-ray film.

- c) Contracts and procedures have been established for providing unreported films to certain referrers. These are kept in the "Medico legal X-rays" file.

The responsibility for justifying the exposure of patients referred from any other source rests with the individual chiropractor who authorises or carries out that exposure.

- (d) If the patient is a woman of childbearing age, ask "are you or could you be pregnant" before proceeding to x-ray her.

If the answer is an unequivocal "no", ask her to sign and date the release form, and file this with her notes.

If she is unsure, consider and discuss the balance of risk of x-raying her against not doing so, and the possibility that her clinical symptoms may be caused or exacerbated by her pregnancy.

The decision to x-ray a patient whose pregnancy cannot be excluded must be a joint one, including properly informed patient consent. Note the clinical indications for the x-ray examination, and file the patient's signed consent form.

If the patient later claims to have been pregnant at the time of examination, inform the RPA and supply him with patient's details and exposure factors.

- (e) Detailed procedures for technical quality assurance are set out in the "TQA" file. In summary, they consist of

every film note any artefacts or departure from acceptable appearance in the exposure log do not use the equipment again until the defect has been cleared or explained and signed off by the RPS

every week process a pre-exposed test film, compare it with the reference strip, and take action according to the instructions supplied

every month review the exposure log and compare the factors and notes with those of a month and a year previously, and with the standardised points chart. Investigate any significant changes.

Clinical audit procedures

every year sample the year's films at random, compare with good practice guidelines*, take corrective action if required.

review the standardised points chart and consult the RPA if changes are needed.

every year review the effectiveness of clinical radiography, in terms of the proportion of films that produce pathological findings or changes in proposed treatment, and consider whether to alter the criteria for x-raying patients

every year review progress on matters arising from the previous audit and any external inspections

record the findings and decisions of the present audit

set implementation dates for changes

set the date for the next clinical audit

The good practice guidelines used in this clinic are

.....
.....
.....

- (f) Patient dose may be assessed from the log book entries.

The procedure for calculating entrance skin dose is given in the "TQA" file.

If it is necessary to assess any other organ dose, effective dose, or the dose to a foetus, contact the RPA.

- (g) European Union reference doses have been considered in drawing up the standardised exposure points chart. An exposure within ± 2 points of the indicated value can be assumed to comply with EU good practice guidelines. Persistent use of exposures outside this range must be investigated by the RPS: the RPA must be consulted and corrective action must be taken.

- (h) The RPA must be consulted and special procedures must be

established before any research programme is introduced which may involve x-ray exposure that is of no direct medical benefit to the person exposed.

- (i) No radioactive medicinal products are used in this clinic.
- (j) Except for rejects (which must be noted in the logbook), and unreported films taken under contract (see (c) above), every clinical film must be reported in the patient's notes.
- (k) Local rules are posted in the x-ray suite. These minimise the likelihood of accidental or unintended radiation dose to any person, provided that the equipment is properly maintained.

Maintenance and inspection schedules are held in the "Maintenance" file. The RPS is responsible for ensuring that they are adhered to.

Example model contracts for external referrers

1. Medicolegal

I undertake that any request from [Anyville Legal Ltd] to Anytown Chiropractic Clinic for an x-ray examination will be written, explicit, and accompanied by sufficient information to allow the practitioner to justify the exposure. Where the request is for unreported films, I undertake to commission a timely evaluation and written report, by a radiologist, medical specialist, or Court medical examiner, of the images provided.

Signed.....[principal solicitor] date.....

2. Other medical professionals

I declare that I am trained and competent to carry out clinical examinations, and interpret plain film radiographs, of [the foot] and thus to refer patients to Anytown Chiropractic Clinic for unreported x-ray examinations. I will make and retain written records of my findings.

Signed.....[chiropractor] date.....

7.9 Universal exposure chart

Patient points + System points = kV points + mAs points

Patient thickness (cm)			Points	kV	mAs
all AP/PA and all cervical	lateral lumbo- pelvic	lateral thoracic (axilla)	0	40	1
			1	41	1.25
			2	42	1.6
			3	44	2
			4	46	2.5
			5	48	3.2
			6	50	4
			7	52	5
			8	55	6.3
	9	57	8		
			10	<i>knee....</i> 60	10
			11	63	12.5
			12	66	16
			13	<i>neck....</i> 70	20
			14	73	25
			15	77	32
			16	<i>PALx....</i> 81	40
			17	85	50
			18	<i>LatLx....</i> 90	63
		19	96	80	
4			20	102	100
5.5			21	109	125
7			22	117	160
8.5		16.5	23	125	200
10		18	24	133	250
11.5		19.5	25	141	320
13		21	26	150	400
14.5		22.5	27		500
16		24	28		630
17.5		25.5	29		800
19	15	27	30		1000
20.5	17	28.5	31		
22	19	30	32		
23.5	21	31.5	33		
25	23	33	34		
26.5	25	34.5	35		
28	27	36	36		
29.5	29	37.5	37		
31	31		38		
32.5	33		39		
34	34.5		40		
	36		41		
	37.5		42		
	39		43		
	40.5		44		
	42		45		

System correction = points

Using the exposure factor chart

1. Measure the **thickness** of the part to be radiographed
2. Find the nearest thickness in the appropriate column of the Patient Points table
 Use the first column for *all* AP and PA views and *all* cervical views
 Use the second column for lateral lumbar and pelvic views
 Use the third column for lateral thoracic views
3. **Read off** the corresponding "**Points**" value. Add 1 - 2 points for muscular patients. Subtract 1 - 2 points for adiposity or osteopaenia.
4. **Add the System Correction** (see "Calibration" below)
5. **Choose** an appropriate **kV** and find the corresponding Points value, then finally
6. **Select mAs** so that

$$\text{Patient Points} + \text{System Correction} = \text{kV Points} + \text{mAs Points}$$

Example

AP lumbar, 25 cm thick	>>>>>	34 points	
System Correction	>>>>>	-1	
very muscular	>>>>>	<u>+2</u>	
Total	>>>>>	<u>35</u> points	
Choose 81 kV	>>>>>	16 points	
so we need another		19 points	>>>>> 80 mAs

Calibration - establishing the System Correction

In an established practice, it is sufficient to work the calculation backwards from a "known good" image of an average-build patient to derive the System Correction.

The initial calibration of a new installation can be made using about 20 cm thickness of 80 gsm photocopier paper to represent soft tissue, and 2p copper coins as "vertebrae". Radiograph the combination as for a PA lumbar spine at 80 - 81 kV and adjust the mAs value until detail can just be discerned in the coins, then calculate the initial System Correction.

Nominal correction values

Focus-film distance	100 cm - 3	150 cm 0	180 cm + 2
Screen speed	200 + 3	400 0	800 - 3
Grid	no grid - 4	10:1 0	16:1 + 2
Generator	1-phase +4	6-pulse 0	HF/12-pulse - 2

Review and adjust the System Correction in the light of clinical experience, and after any changes e.g. to processor temperature or screen speeds.

7.10 Compliance requirements for BCA members using Ionising Radiation

Introduction

Authorities in the United Kingdom generally encourage self-policing by responsible professional bodies as a means of assisting members to comply with regulations relating to the use of ionising radiation. The BCA has in place an X-Ray Standards Committee to oversee protocols and offer advice to BCA members who are involved with the use of ionising radiation.

The British Chiropractic Association (BCA) requires its members to observe and comply with the following:-

1. The BCA will retain a Medical Physics Expert (MPE) to act as its Radiation Protection Adviser (RPA). His role is to provide consultancy advice and assist with ensuring the compliance of BCA members with regulations relating to the use of ionising radiation. The BCA-nominated MPE must be familiar with chiropractic and chiropractic radiography. Members seeking access to the BCA's MPE should contact BCA Head Office.
2. The MPE will report directly to the BCA X-ray Standards Committee (XSC). He will provide a formal report of his activity biannually or whenever changes in legislation necessitate updating of advice to the membership.
3. Members shall notify the BCA of their intention to use, or continue to use, ionising radiation. Where they are responsible for a facility housing x-ray equipment they are required to notify the HSE.
4. Those members fulfilling the role of Employer for the purposes of the *Ionising Radiation Regulations 99* must, in the case of new installations, copy their critical examination and acceptance test report (including a list of the actions proposed to remedy any defects) and send it to the XSC.
5. The initial inspection must comply with all relevant regulations in force at the time. Members shall also comply with the XSC Guidelines, particularly in relation to the safety of premises and equipment and the establishment of good radiological practice and appropriate records.
6. Members' x-ray facilities should be re-inspected by an RPA at least every 3 years. A copy of the report and defect correction schedule should be sent to the XSC.

7.10 Compliance requirements for BCA members

7. The XSC may instruct the Association's MPE or another suitably qualified and appointed specialist to carry out an inspection investigation or audit of any member's practice at any time. Notice of such inspections shall be at least 2 weeks.
8. Members are free to choose whom they should use for their own RPA advice and re-examination work. The BCA recommends that members appoint an RPA/MPE accredited by the Institute of Physics and Engineering in Medicine.
9. The XSC will advise, defend and represent BCA members in relation to their use of x-rays, subject to their having complied with existing legislation and x-ray guidelines They will also work to protect their continued autonomy in relation to x-rays in chiropractic.

Failure to comply with the conditions detailed above may affect future membership of the BCA.

IRMER Schedule 2 lays down the syllabus of training required for practitioners and operators. The sections applicable to chiropractic are

- 1.1 Properties of radiation
attenuation of ionising radiation
scattering and absorption
- 1.2 Radiation hazards and dosimetry
biological effects of radiation
risks/benefits of radiation
dose optimisation
absorbed dose, dose equivalent, effective dose, and their units
- 1.3 Special attention areas
pregnancy and potential pregnancy
infants and children
medical and biomedical research
health screening
high dose techniques
- 2.1 Patient selection
justification of the individual exposure
patient identification and consent
use of existing appropriate radiological information
alternative techniques
clinical evaluation of outcome
medicolegal issues
- 2.2 Radiation protection
general radiation protection
use of radiation protection devices patient
personal procedures for untoward incidents involving overexposure to ionising radiation
- 3.1 Statutory requirements and nonstatutory recommendations
regulations
local rules and procedures
individual responsibilities relating to medical exposures
responsibility for radiation safety
routine inspection and testing of equipment
notification of faults and Health Department hazard warnings
clinical audit

- 4.1 General diagnostic radiology
 - fundamentals of radiological anatomy
 - fundamentals of radiological techniques
 - production of x-rays
 - equipment selection and use
 - factors affecting radiation dose
 - dosimetry
 - quality assurance and quality control

- 4.2 Specialised techniques
 - image intensification/fluoroscopy
 - digital fluoroscopy
 - computerised tomography scanning

- 4.3 Fundamentals of image acquisition etc
 - image quality vs radiation dose
 - conventional film processing
 - additional image formats, acquisition, storage and display

7.12.1 Protocol for the QA of Computed Radiography Systems

Routine QA Tests

This document describes a series of tests to assess CR plate and reader performance. The tests are intended to monitor image quality and sensitivity.

All the tests described should be performed on all available reader systems. This document is intended as guidance. For more specific set-up details the local medical physics department should be consulted.

List of equipment

- Tape measure
- Adhesive tape
- 1 mm Copper filtration (>10 x 10 cm)
- TOR RAD or TOR CDR test object

In all tests described the unique plate identification code should be recorded, and the same tube and generator should be used each time the tests are performed.

1 Detector dose indicator Monitoring

Purpose: To monitor system sensitivity, and consistency of relationship between cassette exposure and detector dose indicator.

Frequency: 1 - 3 monthly

- a) Place a cassette (e.g. 24cm x 30cm - the same cassette should be used each time this test is performed) on the couch at 1m from the focus and centred in the x-ray beam. Set the collimation to cover the entire cassette.
- b) Place filtration in the beam and set a kVp as indicated in below.

CR system	Filtration	Tube Voltage (kVp)
Agfa	1mm Cu	75
Kodak	1mm Cu	80
Fuji	1mm Cu	80

- c) Set a manual mAs (this value should be determined in consultation with medical physics) and expose.

d) Read the plate immediately using the following parameters

Agfa: S=200
system diagnosis/flat field processing and linear sensitometry.

Kodak: Pattern mode.

Fuji: semi-auto. L=1 or 2

e) Record the detector dose indicator, i.e. lg M – Agfa, EI – Kodak, S - Fuji.

Tolerance: This detector dose indicator should be compared to a baseline value obtained under the same conditions (i.e. same x-ray tube, distance, kV, filtration, mAs, plate).

Remedial level:

Agfa: lg M value should lie between

(Baseline +0.08) and (Baseline-0.10)

Kodak: EI should lie between

(Baseline +80) and (Baseline-100)

Fuji: S value should lie between

Baseline+25%) and (Baseline -17%)

Suspension level:

Agfa: lg M value should lie between

(Baseline +0.18) and (Baseline-0.30)

Kodak: EI should lie between

(Baseline+175) and (Baseline-300)

Fuji: S value should lie between

Baseline+100%) and (Baseline-33%)

2 Uniformity

Purpose: To monitor image quality by assessing the uniformity of the system.

Frequency: 1-3 monthly

- a) Select any cassette (a different cassette should be tested each time this test is performed).
- b) Use as large a focus to detector distance as possible and open the collimators so that the X-ray field covers the entire detector.
- c) Expose the detector at as described for test 1.
- d) Visually inspect the images for non-uniformities.

Note: Images acquired for the detector dose indicator monitoring test should also be inspected for non uniformities.

Remedial level: Images should not have obvious artefacts.

N.B. This is a test of the reader. To test the whole system it would be necessary to test several plates at each 1-3 monthly interval

3 Threshold Contrast Detail Detectability

Purpose: To monitor image quality by assessing the visibility of low contrast details

Frequency: 3 - 6 monthly

- a) Place TOR RAD or TOR CDR test object on the table with a focus - receptor distance of 1-1.5m.
- b) Collimate to the cassette.
- c) Place 1mmCu filter in the beam.
- d) Expose at 70kVp with a manual mAs (this value should be determined in conjunction with medical physics).
- e) Read the cassette using the following parameters

Agfa: S=200,

examination type - 'System Diagnosis'
processing - 'Flat Field'

Fuji: Readout mode - 'semi-auto' with test/sensitivity GA=1

Kodak: Mode - 'Pattern' with raw data and no edge enhancement

- f) Record the detector dose indicator.
- g) Make three more exposures under the same conditions.
- h) Window and level the images so that background noise is perceptible.
- i) Print the images onto the largest film size available.
- j) View the image on a masked light box, and score each detail size using fixed distance viewing (<1m). If no hardcopy printer is available, score the images on a reporting workstation, optimising window and level settings for each detail size.
- k) Calculate the mean number of visible details (average over all detail diameters)

Remedial level: Average number of visible details reduced by two from baseline

4 Limiting spatial resolution

Purpose: To monitor image quality by assessing the resolution of the system

Frequency: 3 - 6 monthly

- a) Place resolution test grid (e.g. TOR RAD or TOR CDR) on a 24 cm x 30 cm cassette at ~1 m. The bars should be angled at 45° to the plate.

N.B. Remember to remove the copper filtration from the beam.

- b) Set 50kVp.
- c) Expose at ~ 2mAs.
- d) Read the image plate using the following parameters.

Agfa: S=200,
examination type - 'System Diagnosis'
processing - 'Flat Field'

Fuji: Readout mode - 'fix' with L=2 and S=200

Kodak: Mode - 'Pattern' with raw data and no edge enhancement

- e) Determine the number of resolvable groups of lines.

Remedial level: Number of resolvable groups reduced by 2 from baseline.

N.B. Other plate sizes may give different resolutions and should ideally be tested.

References

- [1] Draft Report of Task Group #10, American Association of Physicists in Medicine, Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems, August 1998
- [2] British Institute of Radiology, 'Assurance of the quality in the diagnostic imaging department', 2001, ISBN 0-905749-48-0
- [3] IPEM draft CR QC protocol
- [4] Samei E, Seibert JA, Willis CE, Flynn MJ, Mah E, Junck KL, 'Performance evaluation of computed radiography systems', 2001, Med.Phys. Vol28 (3) p361-371.

7.12.2 Protocol for the QA of Direct Digital Radiography Systems

Routine QA Tests

This document describes a series of tests to assess digital detector performance. The tests are intended to detect artefacts and test image quality and sensitivity.

All images should be acquired with a minimal amount of pre-processing and a linear Look Up Table (LUT) applied, unless otherwise stated.

Note: These tests are in addition to tube and alignment checks

This document is intended as guidance. For more specific set-up details the local medical physics department should be consulted.

List of equipment

- Tape measure
- Adhesive tape
- 1 mm Copper filtration (>10 × 10 cm)
- TOR RAD or TOR CDR test object

1 Detector dose indicator Monitoring

Purpose: To monitor system sensitivity, and consistency of relationship between detector exposure and detector dose indicator.

Frequency: 1 - 3 monthly

- a) Set up the detector at 1 m from the focus and centred in the X-ray beam. Set the collimation to cover the entire detector.
- b) Place 1 mmCu filtration in the beam and set 70 kVp.
- c) Set a manual mAs (this value should be determined in consultation with medical physics) and expose.
- d) Record the detector dose indicator.

Tolerance: The indicated detector dose indicator should be compared to a baseline value obtained under the same conditions (i.e. same distance, kV, filtration, mAs).

Remedial level: Baseline \pm 20%.

Suspension level: Baseline \pm 50%.

2 Uniformity

Purpose: To monitor image quality by assessing the uniformity of the system.

Frequency: 1 -3 monthly

- e) Set a 1 m focus to detector distance and open the collimators so that the X-ray field covers the entire detector.
- f) Expose the detector at as described for test 1.
- g) Visually inspect the images for non-uniformities.

Note: Images acquired for the detector dose indicator monitoring test should also be inspected for non uniformities.

Remedial level: Images should not have obvious artefacts.

3 Threshold Contrast Detail Detectability

Purpose: To monitor image quality by assessing the visibility of low contrast details.

Frequency: 3 - 6 monthly

- a) Place TOR RAD or TOR CDR (figure 1) (or equivalent) test object on the detector with a focus to detector distance of 1 m.
- b) Collimate to the test object.
- c) Place 1 mmCu filter in the beam.
- d) Expose at 70 kVp with a manual mAs (this value should be determined in conjunction with medical physics).
- e) Record the detector dose indicator.

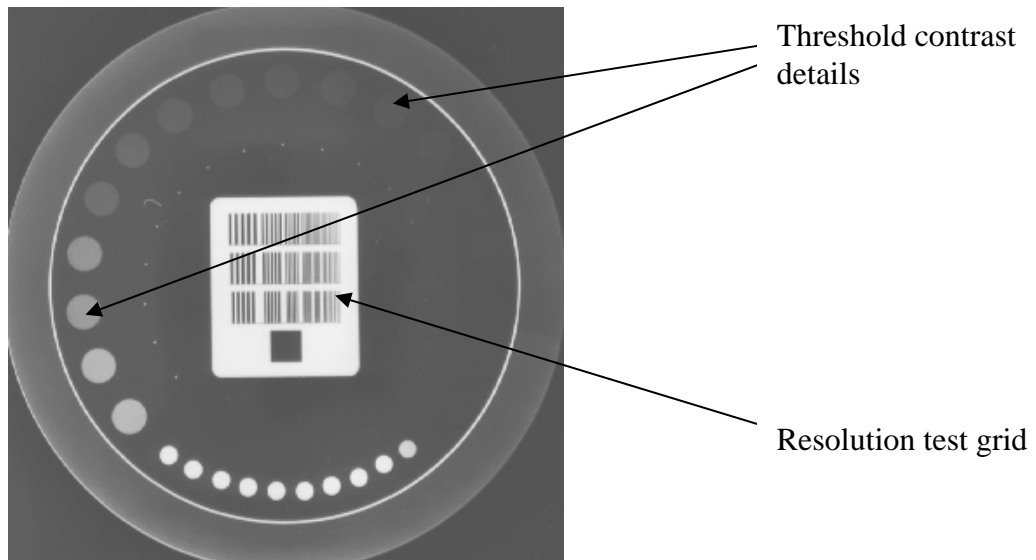


Figure 1. The TOR RAD test object

Make three more exposures under the same conditions.

- f) Window and level the images so that background noise is perceptible.
- g) Score the images on a reporting workstation, optimising window and level settings for each detail size.
- h) If softcopy viewing is not available, print the images onto the largest film size available. View the image on a masked light box, and score each detail size using a fixed viewing distance (<1 m).
- i) Calculate the mean number of visible details (average over all detail diameters).

Remedial level: Average number of visible details reduced by two from baseline.

4 Limiting spatial resolution

Purpose: To monitor image quality by assessing the resolution of the system.

Frequency: 3 - 6 monthly

- a) Place resolution test grid (e.g. TOR RAD, figure 1, or TOR CDR) on the detector at ~1 m from the tube focus.

N.B. Remember to remove the copper filtration from the beam.

b) Set 50 kVp.

c) Expose at ~ 2 mAs.

d) Determine the number of resolvable groups of lines.

Remedial level: Number of resolvable groups reduced by 2 from baseline.