Tandem Gait
Description-The patient is instructed to walk heel to toe, both forward and backward directions. The gait is observed for abnormality.
Significance-Positive; Abnormal balance
Indication-Cerebellar disease; posterior column; atherosclerosis; multiple sclerosis; CNS tumor; subluxation.

Trendelenberg
Description-The patient stands on one leg while the other leg is flexed at both the hip and knee to ninety degrees.
Significance-Positive; If the hip on the raised leg side drops lower than the standing leg side.
Indication-Hip disease; Gluteus medius weak on the weight-bearing leg.

Tromner’s
Description-While the patient is sitting, the practitioner gives a sharp upward tap to the supinated middle finger and ring finger.
Significance-Positive; Finger flexion occurs.
Indication-Possible upper motor neuron disorder.

Underburger's
Description-The patient is instructed to march on the spot with both arms outstretched, eyes closed, and the head extended and rotated.
Significance-Positive; Loss of balance.
Indication-Basilar ischemia.

Valsalva
Description-The patient is instructed to hold their breath and bear down. This increases the pressure in the spinal canal, shunting the blood back to the paraspinal plexus, increasing the pressure near the space occupying lesion.
Significance-Positive; Gives pain in the area of the space occupying lesion.
Indication-Disc disease or other space occupying lesion.

Vertebral Artery Occlusion
Description-The patient lies supine with the neck in extension, rotation and lateral flexion.
Significance-Positive; If the patient turns pale, becomes dizzy, nauseated or suffers blurred vision within thirty seconds.
Indication-Basilar insufficiency.

Well Leg Raise
Description-S.L.R. with foot dorsiflexion on the asymptomatic side of a sciatic patient.
Significance-Positive; Reproduces pain on the symptomatic side.
Indication-Disc syndrome; space occupying lesion; sciatic nerve root involvement.

Wright’s
Description-While the patient is sitting, abduct their arm above the head. Palpate the radial pulse through the arc of 180 degrees.
Significance-Positive; Decrease or obliteration of radial pulse.
Indication-Pectoralis minor involvement.

Wrist Clonus
Description-The practitioner vigorously applies quick, repeated extensions of the patient's wrist, then holds it in extension.
Significance-Positive; repeated, rapid, involuntary flexion/extension of the wrist.
Indication-Upper motor neuron lesion.
Since their contemporaneous discoveries in 1895, chiropractic and roentgenology have been linked in many of their technologic and applied advances (1,2). With the use of plain film radiography, chiropractic examination procedures changed from reliance solely on symptomatology and palpatory findings to include viewing of representations of underlying spinal and soft tissues. This new found ability advanced the science and art of chiropractic serving as an important tool in evaluating various clinical and theoretical approaches.

In 1932, Saussers, a chiropractor, took the first 14” × 36” anterior-to-posterior (AP) full spine radiograph. He later produced a 20” × 72” full body film in 1935 (3,4). The first X-ray machine west of the Mississippi was brought to Davenport, Iowa by B.J. Palmer in September of 1910. His X-ray research at the Palmer Research Center used thousands of patients and concluded that 64% of palpatory findings were in error, when compared to radiographic discoveries (5).

Gonstead (6) furthered the use of x-ray by developing a system of marking and analyzing the spine and pelvis for biomechanical misalignments. This system depends on strict patient positioning (7–9).

Today’s chiropractors use radiographs to evaluate the acceptability of a patient for chiropractic care, uncover contraindications to chiropractic treatment, discover information that will alter the type, frequency, or force of treatment, assess the kinesiopathologic components of the vertebral subluxation complex and provide a teaching tool for patient education (Fig. 5.1).

Many texts (2,10) adequately cover the study and detection of those conditions that require allopathic intervention or alter the preferred biomechanical treatment. The purpose of this chapter is not intended to duplicate previous work, but instead to focus on the evaluation of the kinesiopathologic components of the vertebral subluxation complex through the appropriate use of plain film radiography.

Kinesiopathologies of the subluxation complex include positional dyskinesia, fixation dysfunction, hypermobility, instability, and changes in the axis of motion (11). As previously discussed (See Chapter 3), kinesiopathologic findings are only one component of the vertebral subluxation complex. The primary function of the doctor of chiropractic is the location and treatment of these biomechanical irregularities and their subsequent manifestations. It is imperative that examinations be performed with the highest degree of accuracy. The chiropractor should use all the readily available tools of inquiry to gain the most cost effective information to best evaluate each case.

When the findings of the history and physical examination indicate a need for an evaluation of the integrity and interrelationships of spinal structures, a roentgenologic examination should be performed.

The plain film radiograph is still the procedure of choice, in both time and cost effectiveness, for examinations of the skeleton (2). This is especially true when the diagnostic inquiry calls for a biomechanical analysis.

**Risks of Ionizing Radiation**

The relative risks of ionizing radiation must be considered whenever selecting the appropriate views for each radiographic examination. It has been well documented that there are potential negative biologic effects of human exposure to ionizing radiation (1,12). Because the biologic consequences of irradiation are cumulative, it is important to consider the risks and make every reasonable attempt to minimize exposure without sacrificing the quality of information obtained (1).

Biologic effects are both dosage and tissue dependent. The radiosensitivity of different tissues necessitates safety standards during a radiographic examination. Tissues that are more differentiated, more mature, and less likely to divide are less radiosensitive than those that are primitive, nondifferentiated, and more likely to divide. The biologic effects of radiation can be divided into two categories: somatic and genetic.

**SOMATIC**

Somatic effects can be subdivided into two groups, local and general. Local injuries were more common early in the study of diagnostic x-rays as experimentation using multiple exposures on various body parts were performed. The frequency of these injuries was reduced as proper usage of radiographic equipment became the norm (2).

Few general effects of exposure have been docu-
Figure 5.1. AP full spine with cervical, thoracic, and lumbar stress radiographs for analysis of the coronal plane kinesiopathologic components of the motion segment.
mented in humans as a result of diagnostic x-rays. Although there are some data which suggests a doubling of the incidence of leukemia in children whose mothers had roentgen pelvimetry performed during pregnancy. After the atomic bomb was dropped on Hiroshima and Nagasaki, the incidence of leukemia was increased proportional to the distance from the hypocenter. There also exist data suggesting an increase in cancer of the thyroid in patients who received therapeutic radiation of the thymus in infancy (10).

Animal experimentation demonstrates that with enormously high levels of whole body exposure, life-span is shortened. There are no data that suggest a shortened life span in radiology technicians who are exposed to increased levels of radiation throughout their lifetime (10).

GENETIC

The genetic effect of radiation is primarily the production of mutations. The gonadal dose seems to be directly proportional to the number of mutations, regardless of the time lapse between exposures. According to Crow (13), 100 R in one dose has the same genetic effect as the same dose given over a longer period of time.

A total dose of 30 to 80 R to the gonads of the entire population would double the existing mutation rate of humans (10,14). The National Academy of Sciences committee on genetic effects of atomic radiation suggests that up to 30 years of age, no more than 10 R be received by an individual, excluding natural causes (10). Because the gonadal effect is of the greatest importance to the entire population in the long term, it is crucial to use diagnostic x-rays judiciously and to apply gonadal shielding whenever possible. An exception would be when shielding obscures a suspected abnormality.

To put into perspective the amounts of radiation required to increase the risk of genetic mutation, the following comparison is made. In 1988, the conference of Radiation Control Program Directors set guidelines for different diagnostic studies performed (15). An AP full spine view using a 400 film screen speed combination yields about 145 mR of total body exposure (16). Gonadal dose would be approximately 20% or about 30 mR. This would mean that a 30-year-old man would have to receive a minimum of 333 AP full spine exposures at 400 speed before the National Academy of Science guidelines would be met. A 1200 speed system with gonadal shielding would require more than 1000 AP full spine exposures to double the risk of the genetic mutation rate. It becomes clear that even pre and post full spine views create a minimal overall risk of genetic mutation.

When assessing radiation from full spine views in comparison with occupational limits set forth by the National Council on Radiation Protection, an individual would be allowed a yearly exposure of the equivalent of 34 AP full spine views taken with a 400 speed system. Using a 1200 speed system would allow for additional exposures. Of course medical exposure risk assessment is different from occupation exposure risk assessment. The comparison is made only to put into perspective the relative risk of diagnostic exposure. Exposure to ionizing radiation causes biologic effects and must always be treated judiciously. The clinical benefit must be weighed and balanced with any potential negative effects.

The use of nutritional measures to counter the effects of ionizing radiation is somewhat controversial. There is some evidence that ingestion of vitamin E, or other antioxidants, may provide some protection from low-dose irradiation (17). This is based largely on work with laboratory animals.

TECHNICAL CONSIDERATIONS

The taking of high quality diagnostic radiographs requires that proper equipment, technique and patient preparation be used.

Equipment

ALIGNMENT

To reduce film distortion, the x-ray equipment should be aligned so that the central ray passes through the center of the grid at exactly 90° to the grid cabinet and the film. To ensure this, the bucky should be held in a vertical position with the cassette and film centered to the primary x-ray beam. The tube should be positioned so that the beam travels horizontally and strikes the bucky and film in a perpendicular fashion at all heights and distances.

COLLIMATION

The use of a field restricting collimator is one of the most effective means of reducing the amount of radiation the patient and the operator are exposed to during a radiologic examination (1). The collimator can restrict the beam to a chosen area of the body. Most collimators are equipped with a light localizer that provides a visual indication of the size and location of the x-ray field. It is imperative that the x-ray beam be restricted to the area of clinical interest and not exceed the size of the film. When the area of interest is smaller than the film, the x-ray beam should be further restricted to only involve that area. It is essential that the patient’s eyes be collimated out of the exposure field during a radiographic examination.

In addition to protecting the patient and the technician from excessive dosage, collimation also increases the quality of the radiograph by improving contrast and detail.
of the film by reducing the amount of scatter radiation during the exposure.

RADIOGRAPHIC GRIDS

Radiographic grids are devices comprised of vertically aligned thin strips of lead that are placed in front of the cassette for the purpose of minimizing the amount of scatter radiation striking the film (1). Scatter radiation, radiation that has already struck an object and has changed direction, is often no longer oriented with the primary beam, and therefore cannot pass through the thin spaces between the grid strips. This reduces the amount of secondary exposure and improves the film quality. Grids are coordinated with the x-ray unit depending on the highest kVp usually used (Table 5.1).

FILM-SCREEN COMBINATION

With the development of film that is more radio-sensitive and with increased illumination from intensifying screens, the amount of radiation required to create an acceptable image, and thus expose the patient has been greatly decreased (Table 5.2). These faster film-screen combinations may result in a slight loss of detail (1), although this is usually not significant enough to affect the quality or amount of information gained from the study.

At the time of this writing, the fastest film-screen combination commercially available for adequate diagnostic study is the ultra high speed Kodak TMH film used with Fast Lanex Rare Earth Screens (18). The result is a 1200 speed system.

Conditions exist where changing the type of film used with a set of intensifying screens can drastically affect the amount of radiation required to obtain a diagnostic film image. For example, when using DuPont Quanta III rare earth screens with Cronex 7 film, a 400 speed system is produced. By only changing to Cronex 4 film, the system is converted to an 800 speed system, greatly reducing patient exposure (19). Practitioners currently using rare earth Lanex fast screens with older film can cut overall MAS by up to 50% just by using Kodak TMH film. These changes do not significantly increase the difficulty in obtaining high quality films and are probably the most cost effective, high patient benefit, radiation safety measures the clinician can implement.

There are situations, such as a potential spinal or extremity fracture, when the need for detail outweighs the benefits of reduced patient exposure. The use of lower speed screens may be more appropriate in these circumstances. It is therefore recommended that a chiropractor have more than one screen/film combination set available, one high speed system of 800–1200 for spinography and one slower speed system, of 200–400, for fracture or pathology evaluation.

PREPATIENT FILTRATION SYSTEMS

Shielding. Because of the high radiosensitivity of certain body parts, such as the eyes, thyroid, breasts and especially the gonads, shielding systems have been developed to guard these structures from exposure whenever possible. It is imperative that these tissues be excluded from the exposure field, unless doing so would obscure an area of interest. When it is necessary that these tissues be irradiated, all efforts should be made to reduce their exposure. This is often accomplished by the use of specialized patient shielding.

Shields are made of lead, copper, aluminum, or combinations of these and are intended to block specific tissues from the x-ray field. Shields fall into two major categories: contact and shadow shields.

The contact shields are placed directly on the patient, especially in front of the eyes or gonads, and are usually held on with straps, velcro, or clips (Fig. 5.2A-B). Shadow shields are either collimator mounted, such as those provided with the Nolan (20,21) (Fig. 5.3) or Sportelli Systems (21,22), or can be side mounted with shields that swing out in front of the patient, like those of the Bolin wedge filter system (Fig. 5.4) (23). Studies have demonstrated that the degree of protection offered by shadow shields is approximately equal to that of shaped contact

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Table 5.1.*
Recommended Grid Ratios for Various kVp*

<table>
<thead>
<tr>
<th>Highest kVp</th>
<th>Recommended Grid Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>8:1</td>
</tr>
<tr>
<td>100</td>
<td>10:1</td>
</tr>
<tr>
<td>110</td>
<td>12:1</td>
</tr>
<tr>
<td>120</td>
<td>16:1</td>
</tr>
</tbody>
</table>

*From Hildebrandt RW. Chiropractic spinography. 2nd ed. Baltimore: Williams & Wilkins, 1985:35.

Table 5.2.
Comparative ESE Values in mR per Exposure Between 1200 Speed Systems at 80° and 40°*4

<table>
<thead>
<tr>
<th>View (86)</th>
<th>1200 Speed @ 40°</th>
<th>1200 Speed @ 80°</th>
<th>NCRP ('89) Median Values</th>
<th>CDRH</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP Cervical 23 cm.</td>
<td>8 mR</td>
<td>10 mR</td>
<td>260 mR</td>
<td>162 mR</td>
</tr>
<tr>
<td>AP Thoracic 24 cm.</td>
<td>23 mR</td>
<td>26 mR</td>
<td>663 mR</td>
<td>465 mR</td>
</tr>
<tr>
<td>AP Lumbar 24 cm.</td>
<td>71 mR</td>
<td>67 mR</td>
<td>884 mR</td>
<td>448 mR</td>
</tr>
</tbody>
</table>

*Dosimetry by Upstate Medical Physics, Inc. Rochester, NY 14609, "Average ESE Exposure to US Population from Diagnostic Medical Radiation," NCRP Report 100, 1989, and "Recommendations for Evaluation of Medical Exposure from Diagnostic Exams" values are from the median ESE, CDRH HHS Pub (FDA) 85-8247.

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shields (1). Gonadal shields can reduce the primary beam by 50% to nearly 100%, depending on the system, providing significant benefits to the patient.

**Compensating Filters.** There are pretarget filtration systems that regulate the amount of radiation striking the patient (20–24) (Fig. 5.5). They are adaptable for taking full-spine or sectional radiographs. These filters, usually aluminum or aluminum copper combinations, attach to the front of the collimator. The aim is to create equal radiodensity of all body parts during the exposure. This allows for specific modifications for different body types and sizes, and reduces patient exposure. These systems may be slightly more time consuming in their application than those with less flexibility, but they produce higher quality radiographs with less patient exposure.

The cervical spine is typically 20 to 30% of the lateral thoracic measurement. Prepatient filtration of this area should provide for satisfactory imaging of the C7, T1 and
the upper thoracic area, without overexposing the cervical spine.

When taking an AP view, the doctor may want to place the top of a prepatient filter to the bottom of the open jaw, this will approximately equalize the density of the lower occiput, mandible and lower cervical areas. The limitations on the quality of the radiograph produced are limited by the skill of the technician instead of equipment restrictions.

LONG WAVELENGTH FILTRATION

The U.S. Food and Drug Administration recently approved a prepatient filter known as the Niobi-x (25). Made from the element Niobium, previously known as Columbium, the filter is placed in the beam at the x-ray tube port. The physical characteristics of Niobium remove low energy x-rays that are of the harmful long wavelengths. Low energy x-rays contribute little to diagnostic quality while increasing patient dose. Scatter radiation is reduced and film quality may also be enhanced.

ULTRA HIGH FREQUENCY X-RAY GENERATORS

In contrast to single phase systems, ultra high frequency generators provide a decrease of 50% in exposure time, lower overall patient dose, as well as increased technical accuracy and consistency of imaging. This technology produces a higher quality image with greater detail and contrast. The high frequency wave consists of sustained penetrating waves. The soft or inefficient radiation is reduced in high frequency generation (26).

X-ray Technique Variables

The most important factors affecting image quality and patient dose are milliamperage, kilovoltage and focal film distance. Milliamperage is the variable that determines the quantity of x-rays produced (1). As the milliamperage is raised, the number of x-ray photons produced increases. The longer the current is sustained, the greater the total dose of radiation absorbed by the patient. The current produced (milliamperage) multiplied by the time (seconds) determines total MAS. Overexposure causes unnecessary risk to the patient. Underexposure also increases risks if the radiograph is not of diagnostic quality and requires a retake. Ideally, the clinician should use the smallest MAS possible to obtain an image of diagnostic quality.

The kVp, or kilovoltage potential, determines the quality or energy of the X-rays produced. High kVp techniques create an x-ray beam with a high percentage of high energy, penetrating photons. These high energy photons are of shorter wavelengths which are generally considered safer for the patient. The higher power reduces patient skin dose, although the higher energy photons do travel further in the body and result in a slight increase in the internal organ dose (27).

High kVp results in a long gray scale of contrast. Ossous detail may be reduced if kVp is beyond an optimal range. The highest kVp technique that yields an acceptable diagnostic image with appropriate contrast is recommended. This is generally 80–110 kVp for the spine and pelvis.

Focal film distance (FFD) or source image distance (SID) affects image quality. As the distance between the tube and patient is increased there is less angulation, or angle of inclination, between the focal spot and the object. This results in a sharper radiographic image by reducing the amount of distortion and magnification (1).

Patient Preparation

The patient is prepared for a radiographic examination by removing all metal, jewelry, hair clips, and dentures if applicable. Trousers with metallic zippers and bras with metal clips or stays are also removed. The patient should be provided with a gown and instructed to put it on with the opening in the back. The patient should be without shoes, unless a heel lift or other orthotic insert is worn.

For females of childbearing age, inquiry must be made as to whether the patient is pregnant. This is best done on the initial history form, again verbally during the preradiographic consultation, and again with a sign in the x-ray room (28). If the patient is unsure as to her pregnancy status, then the “10-day rule” should apply. The 10-day rule excludes the taking of all but emergency films at any time during the menstrual cycle except for the first 10 days after the onset of menses. This rule should be followed to reduce the risk of first trimester fetal irradiation, when the fetus is most susceptible to exposure. The exception to this rule is when the ramifications of not taking the film puts the mother at serious risk (29).

Recent reports concerning the application of the “10-day rule” suggest that when recommended safety precautions are used the risk of injury to the patient or to her progeny from irradiation of diagnostic x-ray, even during the first trimester, is so minimal that pregnancy termination is rarely justified (30).

Many doctors tape metallic objects (BBs or lead shot) onto the patient at landmarks such as the vertebral prominence, L5-S1, superficial marks such as moles and scars or areas of positive clinical findings. This helps to compare apparent relationships accurately between osseous structures and examination findings (Fig. 5.6A-B). If a BB is placed at the inferior aspect of the vertebral prominence, assuming it is C7, and the doctor finds that on the lateral film the BB is viewed at the inferior aspect of C6 instead, a more accurate reference point for palpation can be used. The doctor should take all efforts to minimize the chance of obscuring crucial structures.
while eliminating both unnecessary and excessive exposure (31). It is important to only take views that have the potential to provide information that will determine or alter treatment (32). To base the radiographic examination on convention or on a predetermined view choice seems imprudent. The view selection should be based on the specific findings of the history and physical examination (See Chapter 4) and should be focused on obtaining information that will determine treatment.

Full Spine Radiography

When a spinal assessment is called for based on the results of the history and physical examinations, full spine weight-bearing films are the views of choice (Fig. 5.7) (24,33). There has been significant controversy about the comparative value of full spine and sectional radiographs. It has been repeatedly recounted that there are inherent drawbacks in full spine films, especially in the areas of film distortion, increased patient exposure, and the difficulty in producing quality films (34). Although these criticisms have been propagated for years with a great degree of emotional devotion, the current scientific literature has found these concerns to be greatly overstated. Phillips' study (35) involving Diplomates of the American Chiropractic College of Roentgenology evaluating sectional and full spine radiographs concluded that although there may be some slight reduction in image quality, the diagnostic value of full spine x-rays appears to be equal to that of sectional views.

The 14" x 36" AP film is probably the single most commonly taken view that provides the greatest amount of information (24) (Fig. 5.8). The obvious advantage of seeing the entire spine and viewing the postural relationships of articular and noncontiguous structures at once, gives the practitioner the benefit of understanding distant effects of spinal dysfunction on the whole spine. If one were only able to view a 8" x 10" of a compensated curve, the cause of the problem could easily go undetected, especially in the case of a patient with a global lateral list.

With the technologic advances in taking full spine radiographs, the patient is exposed to less radiation than standard sectional views when the entire spine must be visualized (1,34,36). To include all vertebral segments during a sectional examination, it is necessary to overlap areas. Consequently, this increases the received skin dosage in those areas caused by the projectional overlap (Fig. 5.9A-B). This is particularly relevant when one considers that the radiosensitive thyroid gland falls within one such area, between C6 and T1, at the overlap of the cervical and thoracic views (1).

In the ongoing effort to achieve specificity when examining and adjusting the spine, the doctor must be certain as to which motion segment is being evaluated or treated. The doctor must first be sure of the number of spinal segments. This information is then correlated with superi-
cial bony landmarks. Because of the anomalous variations in individual spines and the reality of missing or overlapping areas when taking sectional views, the AP full spine radiograph is the only sure way to determine the number of spinal segments.

Most full spine films should be taken at a FFD of 84". This distance is recommended for all those taking 14" × 36" films to reduce distortion and magnification and to increase film quality (3,31). Obviously, space limitations or state regulations in some offices may preclude this focal film distance.

DISTORTION, DISTANCE, AND FILM SIZE

The angle of incidence (AI) of the furthest ray penetrating the patient and exposing the film creates the most distortion in the image. The quality of the radiograph is improved when the angle of incidence is minimized, producing less projectional distortion (PD). This is done primarily by increasing the focal film distance. Table 5.3 provides the angles of incidence for common radiographic situations. The angle of incidence at the periphery of an 8" × 10" film taken at 40" is 7.2°. To achieve this same angle on a 14" × 36" radiograph the FFD would have to be 144". The AI for a 14" × 17" film taken at 40" is 12.0°.

A 14" × 36" full spine radiograph taken at 84" will provide the same AI. Although the shorter FFD normally used for full spine spinography, 72" to 84", does increase the PD to some extent, its effect on the usefulness of the film is minimal. Adjacent structures have similar PD and therefore will illustrate dyskinetic relationships when present (6,37,38).

SPLIT SCREENS

It has been long thought that with 14" × 36" full spine films there was an inherent sacrifice in film quality. This resulted primarily from the difficulty in exposing body

<table>
<thead>
<tr>
<th>View</th>
<th>Distance</th>
<th>Angle of Incidence</th>
</tr>
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<tbody>
<tr>
<td>8 × 10</td>
<td>40&quot;</td>
<td>7°</td>
</tr>
<tr>
<td>8 × 10</td>
<td>72&quot;</td>
<td>4°</td>
</tr>
<tr>
<td>14 × 17</td>
<td>40°</td>
<td>12°</td>
</tr>
<tr>
<td>14 × 17</td>
<td>60°</td>
<td>8°</td>
</tr>
<tr>
<td>14 × 17</td>
<td>72°</td>
<td>6.7°</td>
</tr>
<tr>
<td>14 × 36</td>
<td>72°</td>
<td>14°</td>
</tr>
<tr>
<td>14 × 36</td>
<td>80°</td>
<td>12.6°</td>
</tr>
<tr>
<td>14 × 36</td>
<td>84°</td>
<td>12°</td>
</tr>
</tbody>
</table>
parts of varying thickness and varying densities on the same film. An early effort to remedy this was to use “split screen” speed intensifying screens (24) to equalize the radiographic image produced by the varied amounts of ionizing radiation passing through the different body parts. Slower screens were used behind thinner body parts, with faster screens behind thicker or more dense parts. This attempt improved film quality signifi-
cantly, although there were still inherent drawbacks. These “split screens” made it difficult to get diagnostic views of certain areas of the spine because of individual size and body types. Clear visualization of the vertebral prominence area, for example, is made more difficult with split screens. Because split screens regulate the amount of illumination of the intensifying crystals after the x-rays have passed through the patient, they require exposing the patient to added radiation (Fig. 5.10).

With improvements in equipment and techniques for taking high quality full spine radiographs without “split intensifying screens,” the use of these screens, with their added patient exposure, is outdated (6,34).

HOMOGENEOUS SCREENS

A system that uses homogeneous, or uniform, intensifying screens is now in common use by the profession (24). This system uses one, usually ultra high speed screen set, for the entire 14” × 36” cassette. It is necessary to use a prepatient filtration system (See Pre Patient Filtration) with these cassettes to produce a radiograph of high quality. Although these systems may be slightly more time consuming in their application, they have the advantages of reducing patient exposure and providing increased flexibility for different body types. As previously discussed, by regulating the x-ray beam before the patient rather than at the intensifying screens, exposure is significantly reduced (See Fig. 5.5). These systems allow for adequate alterations for most body types and usually result in higher quality radiographs.

PATIENT MEASUREMENT

The patient should be measured with accurate calipers. Measurements are made at the following locations for the full spine lateral view; the greater trochanters, the thinnest area of the waist, the chest under the axillae, and the neck (Fig. 5.11A-C). For the AP view, measurements should be made at the neck, sternum, and the largest part of the abdomen (Fig. 5.12A-C). Most importantly, the doctor should follow a consistent measuring procedure that is accurate and correlated with the technique chart used. There are sophisticated calipers that when properly calibrated will provide exposure factors during measuring and reduce the set-up time for the examination (Fig. 5.13) (39).

PATIENT POSITIONING

The patient is positioned in a weight-bearing position to properly assess the spine and pelvis at interface with gravity (33,40,41).

AP Full Spine. For the AP radiograph, the patient should be in the center of the bucky with heels parallel to the bucky and perpendicular to the beam. A scribed line,
Figure 5.9. A, When sectional radiographs are used for the entire full spine, it is necessary to have projectional overlap. B, The full spine radiograph eliminates overlap and thus reduces patient exposure.

Figure 5.10. Split or multispeed screens expose the patient to additional radiation by regulating the amount of exposure after the patient has been exposed.

parallel to the bucky on the floor, helps to align the patient. There are various devices that are placed on the floor for the patient to stand on, which assist with the set-up. Some have lines parallel to the bucky, others also have lines that are perpendicular, and some have outlines of feet (Fig. 5.14A) (42).

To get the best position, the patient should be instructed to stand in front of the bucky, face the tube, and shuffle backward by taking small equal steps until "any part of the body just touches the bucky" (6). The doctor should check to be sure that the patient is situated in the center of the bucky, with the heels parallel to it (Fig. 5.14B). The patient must not be leaning against the bucky or toward either side. The natural foot flare of the patient should be maintained.

Figure 5.11. A, Measuring for the lateral full spine radiograph. Neck measurement. B, Measuring under the axillae. C, Measuring over the greater trochanters.
The patient is instructed to open the mouth with the head placed at such an inclination that both the mandible and the occiput are not obscuring the upper cervical area. This can be ensured by stretching a string from the origin of the central ray to the lateral aspect of the atlas transverse process, thereby observing that both the mandible and occiput are clear of the upper cervical structures. Head rotation caused by joint dysfunction should be maintained. The patient is instructed to exhale and hold the breath. The exposure is made during full expiration.

**Lateral Full Spine.** There are many different procedures used when taking lateral full spine films. The patient is generally positioned so that the heels are placed perpendicular to the bucky. The patient’s lumbar spine should be in the center of the bucky, ensuring that the cervical spine is within the field of exposure, and that the eyes can be excluded during collimation. The shoulder near the bucky should be in contact with it.

The arms are positioned out of the way of spinal structures. This can be done in a number of ways; the patient may be placed so that both arms are resting in front on a horizontal bar (Fig. 5.15A) or he/she may hold onto a vertical pole at the front (Fig. 5.15B). Also, the patient can be placed in a “swimmers” position (Fig. 5.15C). In all cases, after placement, check to ensure that the patient is not rotated or assuming a “leaning” position.

Alterations of positioning may be helpful depending on individual body types. For example, when taking a lateral view of a hyperkyphotic woman with a Dowager’s hump, it may be helpful to pull her shoulders somewhat forward to diminish the obstruction of both scapulae and to allow for clear viewing of the cervico-thoracic junction.

Generally, the lateral film is taken as an aggregate of two 14” x 18” exposures on a single piece of 14” x 36” film (6). This is done to minimize distortion and for better visualization of the disc spaces. The first exposure is usually of the cervicothoracic spine taken on the top half of the film. It is imperative that the eyes be excluded from the x-ray field for patient safety. The thoracolumbar spinal view is then taken on the lower half of the same piece of film.

The method of taking two views on the same film allows for a complete postural analysis in the sagittal plane and helps with film handling and storage in that
both the AP and lateral full spines are on 14" X 36" films. There are, however, inherent problems that must be solved in placing both views on the same film. Because of the angle of incidence of the x-ray beam, if one were simply to move the tube when taking both views, there would be an area of the spine excluded from the radiographic image (Fig. 5.16). To include this area in the image, a film shift must accompany the tube shift. There are a number of methods to do this.

The conventional method for performing a two exposure lateral full spine was to take the upper view first, then raise the film 4" and realign the tube with the center of the lower half of the film. This 4" shift ensures, with even the largest patients, that the entire spine would be included on the radiograph. A problem still existed in that often large areas of the spine were overlapped and exposed twice.

An alternative method, which minimizes the overlap area, is to triangulate the area that would be missed using a chart devised from simple trigonometry and make the film shift dependent on the size of the patient (Fig. 5.17) (Table 5.4).

There is also a single exposure full spine technique. It is imperative that this view be taken at a long FFD, at least 90", to minimize distortion. Although this exposure places increased stress on the tube, the use of elaborate prepatient filtration and a high screen/film speed combination makes its clinical utility more feasible.
Radiographic Contraindications

OSSEOUS CONSIDERATIONS

The chiropractor should be aware of the existence of underlying pathologic conditions that may contraindicate the safe delivery of adjustments. The osseous structures should also be checked for the presence of fracture or dislocation to determine if an applied force, or thrust, would cause further bony or articular deformity or increase neurologic deficit (see Chapter 12).

As an advanced osteolytic process progresses, and the pressure from neoplastic growth causes resorption of supportive trabeculae, the bone is weakened. Neoplastic growth replaces first medullary tissue and finally the osseous cortex. The structure may then become so fragile that it is susceptible to spontaneous collapse (2). The bone in this condition would be much too weak to be used as a lever arm during an adjustment; therefore, osseous adjusting would be contraindicated.

SPINAL INSTABILITY

Absence, severe erosion, or rupture of the transverse ligament of atlas, or other spinal ligaments, renders the spine unstable and risks potential neural damage from even the most “mild” adjustments. An involved segment should not be adjusted in the direction normally supported by the damaged ligament. This does not suggest that other spinal segments cannot be safely adjusted, providing that the adjustment does not affect the unstable segment in the direction of risk. The plain film radiograph, in stressed positions, provides the information needed to arrive at these determinations (43).

There are other spinal instabilities that are within the scope of chiropractic practice and may demonstrate improvement through a course of adjustments. Nevertheless, the evaluation of spinal instabilities is complicated by the many differing definitions that exist on the subject. White and Panjabi (43) define clinical instability “as the loss of the ability of the spine under physiologic loads to maintain relationships between vertebrae in such a way that there is neither damage nor subsequent irritation to the spinal cord or nerve roots, and in addition, there is no development of incapacitating deformity or pain due to structural changes.”

Jackson (44) found in her clinical observations that instability of the cervical spine was present when the lateral x-ray demonstrated dynamic changes in vertebral position or motion in the flexion and extension views.

Kirkaldy-Willis (45) describes instability as the second of three phases of degenerative joint disease. He indicates

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**Table 5.4.**

<table>
<thead>
<tr>
<th>Measurement of T10 to Film</th>
<th>Film Shift</th>
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<tr>
<td>8”</td>
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**RADIOGRAPHIC ANALYSIS**

Analysis of the radiograph should proceed in a systematic and methodical manner to minimize oversights and best evaluate the data contained within the films. The films should be evaluated to rule out and analyze fractures, dislocations, anatomic anomalies, biomechanical relationships, instabilities, and gross or subtle osseous or soft tissue abnormalities.
that repeated trauma and continuing stress on the three joint complex causes stretching or attenuation of the capsular ligament and increased damage to the intervertebral disc, thus causing laxity of the capsule and bulging of the disc. This leads to an increase in the abnormal biomechanics of the joint. The wide range of definitions regarding this subject makes evaluation more difficult because any test must be definition specific.

Of the tools used for determining instability, static and stress radiographs and cineradiography are most common (34, 46). Cineradiographic studies are valuable in that they allow the clinician to visualize the functional spinal unit in a dynamic manner and allow for predictions of the physiologic and anatomic changes associated with dysfunction. A retrospective study (47) demonstrated videofluoroscopy (VF) to be more accurate or superior in detecting cervical spine instability than plain film. This study suggested early use of VF in evaluation and management of cervical spine injuries. Cost considerations, however, usually place this procedure out of the realm of most evaluations.

Plain film radiographs, both neutral and stressed, can be used in the evaluation of instability. Consideration must be made for projectional distortion (PD), the quality of the radiographic image, and the experience of the clinician.

The accuracy of instability evaluation can be adversely affected by PD that can give the evaluator the impression that the continuity of the ligamentous structures has been lost, when no damage has in fact occurred. It is therefore recommended that a FFD of at least 72° or greater be used when evaluating for instabilities. At these longer distances, PD is greatly reduced and the accuracy of evaluation is increased (43).

Relative Considerations

Conditions that require alteration in the force, frequency, or osseous site of contact can also be uncovered from the plain film radiograph. Osteoporosis (viewed as osteopenia) may require an alteration in the magnitude of force applied during a treatment, providing that if the severity does not contraindicate chiropractic adjustments entirely. Decreased bone mass associated with osteoporosis weakens the bone. To be observable on a radiograph, at least 30 to 50% loss of bone tissue must occur (2). In the osteoporotic spine, the chiropractor should avoid using the weakened transverse, mammillary processes or ribs as lever arms, and relocate the force of the adjustment to more stable structures, such as the spinous process or spinolaminar junction.

ANALYZING THE FULL SPINE FILM

Before discussing the marking procedure used with the Gonstead full spine approach, it is important to reiterate that this marking system should not be used as the sole criteria for locating the dysfunctional motion segment. This determination is made after a comprehensive history and physical examination (See Chapter 4). The marking system is used to determine the positional dyskinesia of the affected motion segment. Combined with motion palpation and dynamic stress radiographs, the kinesiopathologic components of the subluxated vertebra are determined, and the pattern of thrust during the adjustment can be ascertained.

Marking the AP Radiograph

GONSTEAD PELVIC MARKING SYSTEM

This system for full spine x-ray analysis provides a method of measuring innominate length and width, femoral head height (leg length inequality), and sacral rotation (6). Recent investigations (7, 8) have found excellent levels of reliability and time-course stability for these procedures (Fig. 5.18A).

Using a standard x-ray marking pencil, the doctor places small dots at the top and bottom portions of the innominate. Then, similar dots are placed at the upper edge of each femur head. Another dot is placed at each junction of the articular processes of the sacrum and the iliae (Fig. 5.18B). Dots are also placed at the center of the S2 tubercle (or S3 if S2 is not visible or is congenitally absent). A small dot is placed at each lateral border of the sacral alae, and at the center point of the pubic symphysis. A dot is placed on the lateral and medial borders of each ilium.

A rolling parallel ruler is used to draw a line connecting the femoral head points. This line is called the femoral head line (FHL) (Fig. 5.18B, Line A). The parallel is then rolled from the FHL upward, stopping at the cephalad innominate point first encountered. A 3-inch line parallel to the FHL is drawn (Fig. 5.18B, Line B), and the ruler is rolled upward to the second innominate, where a similar line is drawn (Fig. 5.18B, Line C). The parallel is then turned 180°, realigned with the FHL, and rolled down to the first point of the caudal innominate, a 3-inch line is drawn (Fig. 5.18B, Line D). The ruler is then rolled down to the dot on the other innominate, where a similar line is inscribed (Fig. 5.18B, Line E).

Innominate measurements are made by placing the left hand edge of the ruler on the line at the top of the ilium and recording the length to the nearest 0.5 mm at its intersection with the line at the bottom. This procedure is repeated on the opposite side. The longer innominate is considered to have deviated in a P1 (posteroinferior or -θX) direction. The shorter innominate is listed as an AS (anterosuperior or +θX). The innominate misalignments are determined in relationship to their articulation with the sacrum.

The shape of the obturator foramina will also appear
changed with a PI or AS ilium misalignment. On the side of the PI, the obturator will appear to be longer diagonally, and shorter on the side of an AS (6).

The ruler is turned so that it is perpendicular to the FHL and is rolled laterally until it intersects with the medial and lateral border marks on each ilium. A 2-inch line is drawn at each of these dots (Fig. 5.18B, Line F). The parallel is then rolled to the S2 (or S3) point, a perpendicular line is inscribed 3 inches caudally, and continued near the pubic symphysis (Fig. 5.18B, Line G).

The innominate rotational component can then be determined in a number of ways. The most common method is by measuring the distance that the pubic symphysis deviates from the perpendicular line drawn from S2 or S3. This represents ilium rotational misalignment around the Y axis. The side of pubic symphysis deviation is the side of the internal (In) misaligned ilium. The opposite side would be listed as an external (Ex) ilium misalignment. The distance in millimeters between the vertical line and the symphysis deviation should be measured. The listing for the ilium misalignment is by convention listed on the side of L5 body rotation.

An alternative method to determine In or Ex misalignment is to observe the shape of the obturator foramina. The shape of the obturators will change with ilium misalignments. The obturator on the side of the Ex ilium misalignment will increase in length at its base, while it will appear narrower on the side of In misalignment (6).

A third method for determining the rotational (±θY) component of ilium misalignment is to measure the width between the medial and lateral borders of the ilium. The parallel ruler is placed on the FHL with the left edge on the medial line of the right ilium. The distance is measured to where it intersects the lateral line. Then, with the ruler parallel to the FHL and with the left edge on the lateral edge of the left ilium, the measurement is made to the medial border line. Each measurement is marked on the lateral aspect of the ilium. The larger measurement represents the In ilium, the smaller the Ex. This procedure is usually used when necessary anatomic structures are not clearly visible.

The edge of the ruler is then placed at the two dots at the superior portion of the sacrum, and a 5-inch line is drawn (Fig. 5.18B, Line I). This represents the sacral horizontal plane line (SHPL) and illustrates whether the sacral base is level or has misaligned inferiorly on one side. The ruler’s leading edge is then aligned with the FHL and rolled upward until it touches the higher of the two sacral points. A 1-inch line is drawn above the lower dot. If this line is not parallel to the FHL, it must be determined if this is caused by an inferior sacral misalignment (±θZ) or from malformation of the sacrum (6) (See Chapter 6). To do this, the doctor locates bilateral points, such as the center of the sacral foramina or the sacral crests, and connects them with lines. Lines drawn through these points are parallel if the sacrum is symmetrical and would not be the cause of the discrepancy between the FHL and SHPL. In this case, the parallel ruler is placed perpendicular to the SHPL and advanced laterally to the dots on each edge of the sacrum. A 2-inch line is then drawn through each of these dots. Along with any sacral rotational misalignment, an inferior sacral listing would be included.

If the sacrum is shown to be malformed, or if the SHPL and FHL are parallel, then the ruler is placed perpendicular to the femur head line and the lines drawn through the dots on the lateral borders of the sacrum are so oriented.
Sacral rotational misalignment (Y axis) is determined by measuring the distance from the S2 or S3 center to the lateral borders of the sacral alae (Fig. 5.18B, Line H). The ruler is placed at the center of the sacrum (S2), and the distances are measured to the nearest 0.5 mm. Distances greater than 7 mm are usually considered significant, although misalignment of any magnitude can be important if clinical findings such as fixation and swelling at the joint are present (6). The greater measurement represents a potential axial rotational dyskinesia in relationship to the ilium, such that one alae has rotated posterior. The sacrum is listed as a P-L or P-R. Rotation of all lumbar segments to the same side is further suggestion of a rotated sacrum (6).

Sacral inferiority is only considered valid if the side of inferiority is not associated with sacral malformation as previously discussed. If there is no evidence of sacral malformation and the SHBL is not parallel to the FHL, then the sacral listing includes the inferior subscript and the listings would be noted PI-R or PI-L.

To evaluate leg length inequality, the lateral edge of the ruler is placed at the edge of the film and is rolled upward until it contacts the more cephalad femoral head. A 2-inch line is then drawn above the lower femoral head.

Leg length inequality is measured by placing the lateral border of the ruler at the lowest femoral head and recording the distance between this point and the line directly above it in millimeters. This is the measured difference (MD) the femoral head has deviated from horizontal but may not be a true measurement of leg length deficiency. Misalignments of the innominate can influence the apparent leg length measurements. Gonstead developed the following procedures for determining the actual anatomic leg length differences and for differentiating them from the apparent physiologic leg length differences; for every 5 mm of AS (+\( \theta X \)) or In misalignment the femur head height will be raised by 2 mm; for every 5 mm of PI (\(-\theta X\)) or Ex misalignment, the femur head height will be lowered 2 mm (6). Combinations of compound ilium misalignments are either cumulative or can neutralize each other, depending on the particular coefficients of misalignment.

A correction of ilium misalignment will improve the apparent leg length discrepancy by the same 1:0.4 ratio. For each 5 mm of AS or In correction, the femur length will be lowered by 2 mm. For every 5 mm of PI or Ex correction the femur length will be raised by 2 mm. To compute this, multiply the ilium correction by 0.4 to determine the leg length change (6). This formula becomes very important when considering the use of a heel or shoe lift (See Chapter 6).

MARKING THE SPINAL SEGMENTS

The purpose of the anteroposterior evaluation is to gather important information concerning scoliosis, intervertebral disc wedging (\( \pm \theta Z \)) and vertebral rotation (\( \pm \theta Y \)) (6,37,38). It also allows visualization of the areas of compensation and helps in the determination of how a particular segment may be adjusted (6) (Fig. 5.19).

The marking of the AP film continues by numbering each segment (Fig. 5.20). The leading edge of the parallel ruler is then placed on the femur head line (FHL) and rolled cephalad to the inferior portion of the L5 facets or to like points at the intersection of the intervertebral
body-transverse shadows. The ruler is then advanced upward on the film comparing each segment to the true horizontal. When a segment is encountered that deviates from the horizontal, it is marked along the transverse axis for the entire length of the ruler. The parallel is again rolled cephalad until a vertebral segment is identified that has resumed a horizontal position.

This procedure is followed upward through the lumbar and thoracic spine with each vertebra being marked that has deviated from the horizontal. The next segment that returns to a horizontal orientation is also marked. Once the thoracic area has been marked, dots are placed on all the uncinate processes of C7 through T3, and at the laminar junctions of C2 (Fig. 5.21). The edge of the ruler is then aligned to the dots placed on the uncinate processes of C7 and rolled caudally to the lower third of the vertebral body and a line is drawn the entire length of the parallel. Similar lines are drawn successively at C6 through C2. If lateral wedging (± θZ) exists, the two lines will diverge laterally to one side or the other. This represents wedging of the motion segment.

The next step in the AP film analysis is the determination of rotation (Y axis). The side of the vertebral body that misaligns posteriorly will exhibit a pedicle shadow that widens horizontally and appears to migrate toward the center of the body. The pedicle on the opposite side will appear to narrow and will appear displaced to the lateral margin of the vertebral body. The inferior articular processes can also be used to help determine body rotation. As the vertebral body rotates, the width of the inferior articular process will appear narrowed on the side of spinous laterality and widened on the side of posterior body rotation (6, 48).

As a check for vertebral rotation, it is often helpful to place a dot at each superior and inferior corner of the body. Lines are then drawn connecting the left upper to the right lower and the right upper to the left lower. The position of the spinous process is compared with the intersection of these two lines. A rotated spinous will deviate towards the lateral border of the body on the same side. Because the long spinous processes are often anomalous, this method can be misleading and should be used only as a check (49). It is important that each segment be analyzed relative to the segment below.

MARKING THE UPPER CERVICAL SPINE

Because of the anatomic and biomechanical differences in the upper cervical spine, the roentgenometric line drawing system is unique to this area (See Chapter 11) (Fig. 5.22). Dots are placed at the intersections of the transverse processes-lateral masses of atlas, bilateral points on the axis body, and at like points on the occiput. The edge of the ruler is placed on the dots of the C2 body, and a line is then drawn the entire length of the ruler (axis transverse plane line). This procedure is followed for the atlas by placing the leading edge of the ruler on the dots made at the lateral mass-transverse process intersection, and drawing a line, the transverse plane line (TPL), the entire length of the ruler. The transverse condyle line (TCL) is then drawn at the two points on the occiput (6).

In the optimally aligned spine these lines should all be relatively parallel. If the TPL and the ATPL diverge in
either direction, it indicates that the atlas may have misaligned laterally (i.e., ±θ Z) toward that side with respect to axis.

If the TPL and TCL are not parallel, it indicates that the occiput has misaligned (i.e., ±θ Z) on that side with respect to atlas. Generally, the TPL and ATPL would be parallel in a case where the occiput is subluxated, because it is rare that the atlas and occiput would both be subluxated.

Rotation of atlas can be determined in a number of ways. The most common is to compare the widths of the lateral masses of C1. The lateral mass that exhibits a wider measurement has rotated anteriorly, whereas the posteriorly rotated lateral mass will appear narrower. This is due to the “kidney bean” shape of the lateral mass and how they appear on the radiograph in different orientations (See Chapter 11) (43).

An alternative method for determining rotation of atlas is to view the space between the odontoid process and the lateral mass on each side. When the atlas rotates posteriorly, the odontoid-lateral mass space widens, whereas the opposite side narrows (6).

To determine the rotation of an occipital condyle subluxation, the rotation of the atlas is noted, since the atlas should compensate opposite the rotational coefficient of occipital misalignment. Occipital rotation therefore is indirectly determined relative to atlas rotational misalignment (6). Other systems of upper cervical x-ray marking have demonstrated good levels of interexaminer reliability (50).

### Marking the Lateral Full Spine Radiograph

#### CERVICAL-THORACIC PORTION

To mark the lateral cervicothoracic view, a standard x-ray marking pencil is used to number the segments to match the numbering on the AP film (Fig. 5.23). Dots are then placed on the inferior portion of the vertebral bodies of C2 through T1, at the anterior and posterior body margins.
dotic physiologic curve should be a smooth, uninterrupted arch and is represented by a line (George’s line) drawn along the posterior aspects of the vertebral bodies. Interruption of this line indicates misalignment of one or more of the cervical segments. The “perfectly” aligned cervical spine would exhibit intervertebral discs that are slightly wedged in the posterior, without anterior or posterior displacement of the vertebral bodies. Thus, the “normal” cervical lordosis would be maintained. This lordotic curve is extremely important in that it helps to maintain the upright posture of the head by balancing the skull over the torso, improves the flexibility of the neck, and helps dissipate the shock of walking, running, and impact trauma (44,51).

In the optimal cervical spine, the IVD plane lines will converge posteriorly at a single point (6). The cervical spine must accommodate the head in a neutral position, and it is here that major compensatory factors cause the cervical spine to deviate from normal. The proprioceptive, visual, and vestibular systems work in concert to assure that the head is kept in an upright posture and body balance is maintained, but in doing so, strength and stability in local and distant areas of the spine may be sacrificed (6,44). In cases of single or repeated hyperextension injuries, or in individuals whose work activity causes prolonged hyperextension of the neck, the cervical physiologic curve may become hyperlordotic. This will present radiographically when the IVD plane lines converge very close to the vertebral bodies.

The most frequently seen cervical physiologic compensatory mechanism is the hypolordotic or kyphotic cervical spine (44,46) (Fig. 5.24). The lower IVD plane lines converge close to the vertebral bodies, whereas the middle and upper plane lines diverge posteriorly. This phenomenon is exaggerated in the kyphotic cervical spine.

The classical interpretation of the lateral cervical marking system is that the line that crosses the closest to the bodies is considered to have misaligned posteriorly and inferiorly (−Z, −θX) (Fig. 5.24, Line A). The greater the degree of inferiority, the closer to the bodies the two lines will intersect (6). The disc plane lines above the posterior-inferior segments will diverge to the posterior and are considered compensatory to the suspected subluxation below. Herbst (6) states that, “there is an extremely high correlation between the actual subluxation and the inferior vertebra in that vicinity—in fact, they correspond almost 100% of the time.” This statement is not always borne out on motion radiographs, which at times demonstrate an inferior segment to be mobile. The neutral radiographic exam should be supplemented with stress x-rays in flexion and extension to determine the motion characteristics of the segment.

MARKING THE LATERAL UPPER CERVICAL SPINE

Analysis of the upper cervical spine is initiated with an evaluation for spinal instabilities similar to other areas of the spine (Fig. 5.25). Special attention must be given to any increased width of the atlanto-dental interval. Here again, there is some disagreement as to what constitutes “normal,” but most authorities indicate that the ADI should not exceed 3 mm in the adult, and 5 mm in children (2). Approximately 20% of individuals with Down’s Syndrome have a congenital absence of the transverse ligament and usually present with an increased ADI. Other factors, such as degenerative diseases and collagen disorders can also cause an increase. The lateral neutral view should not be used exclusively to determine the ADI, because a torn transverse atlas ligament may not cause an apparent increase until the joint is stressed during flexion (46).

The lateral cervical analysis is concluded by placing two dots on the C2 odontoid process, one centrally at its base, and the other at its superior margin (See Chapter 11). The line drawn through these points is called the “odontoid line.” Another line is drawn perpendicular to the odontoid line and is placed through the middle portion of the C2 body and is designated the “odontoid perpendicular line” (6).

The atlas A-P plane line is formed by a line drawn through two dots placed at the anterior tubercle and posterior arch of C1. If the posterior ring of atlas is viewed on the radiograph as divided, then the dot is placed in the middle of the broadened image of the posterior arch (6).

Two dots are placed at the anterior and posterior borders of the foramen magnum, and a line is drawn through these points. This line depicts the occipital “foramen magnum” line and represents the position of the skull. Because it can be very difficult to determine this line, the
position of the skull may need to be determined by visualization of the relative position from the lateral cervical x-ray.

In optimal upper cervical alignment, the foramen magnum line, the AP atlas plane line, and the line perpendicular to the axis odontoid line should be relatively parallel. Deviations from this ideal indicate a potential upper cervical misalignment. When the AP atlas plane line and the odontoid perpendicular line diverge towards the anterior, an anterior-superior atlas misalignment (AS) \((-\theta X)\) is demonstrated. If these lines converge towards the anterior, then an anterior-inferior (AI) \((+\theta X)\) atlas misalignment is depicted (See Chapter 11).

When the AP atlas plane line and the foramen magnum line are not parallel, then the occiput is misaligned with respect to atlas. If these lines diverge towards the anterior, then the occiput is misaligned in an anterior-superior (AS) \((-\theta X)\) position. If these lines diverge to the posterior, a posterior-superior (PS) \((+\theta X)\) occipital misalignment is noted (6).

**MARKING THE LATERAL THORACIC AND LUMBAR RADIOGRAPH**

Although there is little convention regarding specific lines to include when marking the lower portion of the lateral full spine radiograph, there exist traditional roentgenometric lines that should be considered (See Chapter 7). The marking of George’s Line, by drawing a line along the posterior border of the bodies (Fig. 5.26), is often helpful in determining the posteriority of a segment. An interruption in George’s line may also suggest the possibility of instability at that level, although confirmation is made by comparison of the lateral view with flexion/extension studies.

An additional radiographic sign found on the neutral lateral radiograph that can be an indication of spinal instability is the vacuum phenomenon, which represents internal disc resorption (Fig. 5.27A-B).

A method has been developed to quantify the posteriority of a segment (16,52). Dots are placed at the anterosuperior and posterosuperior corners of the vertebral body below the segment in question. A line is drawn connecting these two dots. Another line perpendicular to this line is drawn descending from the posterosuperior point.

![Figure 5.25. Neutral lateral upper cervical spine from a full spine radiograph with roentgenometric lines included.](image1)

A dot is then placed at the posterosuperior corner of the problem vertebra, and a line is drawn parallel to the descending line from this point. The distance is then measured between these lines which represents the amount of retrolisthesis (Fig. 5.28).

An evaluation of patient positioning on the projected amount of retrolisthesis was studied. An artificially articulated skeleton was rotated \((\pm \theta Y)\) and lateral radiographs were taken in three positions. The amount of retrolisthesis was compared for the three radiographs (Fig. 5.29A-C). With varying degrees of patient axial rotation the retrolisthesis of L3 and L5 are measured and found to be consistent and not affected by axial rotation.

The drawing of Ulman’s Line to help determine anterolisthesis is also frequently used. Meyerding’s spondyloolisthesis classification lines (See Chapter 7), Hadley’s “S” curve, Macnab’s line for facet imbrication, the lumbosacral angle, the sacral base angle and the lumbar gravita-
Figure 5.27. A, Radiograph of a cadaver’s lumbar spine illustrating the vacuum phenomenon at L5 and L4. B, Specimen of same cadaver sample showing internal disc resorption at L5-S1 and L4-L5.

Figure 5.28. Roentgenometric lines used for calculating the amount of retrolisthesis for a lumbar segment. Modified from Plaugher G, Cremata EE, Phillips RB. A retrospective consecutive case analysis of pre-treatment and comparative static radiological parameters following chiropractic adjustments. J Manipulative Physiol Ther 1990;13:500.

tional line are all helpful in providing useful postural information from the lower lateral lumbar radiograph (53,54).

The lateral view of the thoracolumbar and lumbosacral areas allows the clinician to visualize the sagittal alignment of the vertebral bodies, the size and shape of the IVDs and to determine structural changes that have resulted from long-term consequences of VSC.

In the normal state, a gravitational line dropped from the center of L3 body should intersect at the midportion of S2 and the mid to anterior portion of the sacral base, respectively (20,34). This posture allows for optimal balance of the trunk over the pelvis, requires less muscular effort for standing and locomotion, and increases the efficiency of the functional spinal units.

In traditional static analysis of the lower spine, Gonstead (6) was primarily concerned with which segments had become displaced posteriorly, or in the case of a L5 spondylolisthesis, which segment had misaligned anteriorly. Very often, sagittal misalignments on the lateral film are easy to visualize without marking their boundaries.

**SPOT RADIOGRAPHS**

Under certain circumstances, it may be prudent to take additional views to obtain information that may revise treatment. If there are questions concerning the acceptability of a patient for care, the anatomic integrity of the
spine, or the specific kinesiopathologic components in question that are not answered from the full spine film, then one or more sectional views may be warranted. Again, it is recommended that only radiographs that potentially provide information that would alter treatment be taken.

If there are areas on the full spine radiograph that because of deficient technique are not clear or leave additional questions, it is suggested that sectional radiographs be taken of the area. The particular rationale and technical considerations for performing these views are discussed thoroughly elsewhere (2).

STRESS RADIOGRAPHS

Positional dyskinesia can be visualized radiographically and exists as disrelationships in the normal anatomic relationship of the functional spinal unit. Neutral static plain film radiography is useful in ruling out fractures, dislocations, and other significant pathologies as well as in assessing the intersegmental relationships of contiguous spinal structures and overall global postural tendencies at interface with gravity. Nevertheless, because of their neutral orientation, static analysis is of limited value in assessing the functional status of a motion segment. The use of dynamic stress radiography has been advocated by many authors (55–64) as an effective method for assessing the functional capacities of a motion segment. These stress radiographs are useful in determining intersegmental aberrances as well as global patterns of spinal dysfunction (65–67).

The information gained regarding motion can be correlated with the neutral static film to substantiate the static position further and to differentiate between a fixation and a hypermobile compensation. This differentiation is important in helping to determine whether a misaligned segment is a candidate for an adjutice thrust or, as in the case of a hypermobile compensation, is contraindicated for such manipulation.

In a healthy functional spinal unit (FSU), anatomic components comprising the joint ultimately determine the overall spinal range of motion. These components are the vertebral size and shape, the zygapophyseal orientation, as well as the ligamentous, capsular, annular and muscular composition.

Normal vertebral motion is described according to Panjabi and White (68) using the international coordinate system:
Clockwise rotation
Extension
Right lateral Flexion
Left lateral flexion
Forward translation
Left translation
Cephalad translation
Counterclockwise rotation
Flexion
Left spinous rotation
Right spinous rotation
Posteror translation
Right translation
Caudal translation

This is referred to as a right-handed system. To determine the translation directions, the right hand is held forward with the thumb pointing upward, the index finger pointing forward, and the middle finger pointing to the left (Fig. 5.30). The directions these fingers point are by convention denoted as positive. To determine clockwise rotation, the thumb is pointed in the direction of the positive pole. The fingers will curl in the clockwise direction (Fig. 5.31), designated as $+\theta$.

Figure 5.30. The fingers of the right hand point in the direction of the positive poles.

DYSFUNCTIONAL SPINAL MOTION

In an injured spine, motion may take on dysfunctional characteristics because of the alteration of the anatomic components. This may consist of an abnormal increase or decrease in the range of motion (ROM) or of changes in the axis of motion of the joint (11, 55, 58, 69).

In the FSU, an abnormal decrease in motion (fixation dysfunction) may arise because of joint pathology (e.g., adhesion formation and contracture, disc lesions and inflammation) (See Chapter 3). This can occur either unilaterally or bilaterally and can exist along a single axis of motion or along multiple axes of motion. Clinically, this dysfunction can be evaluated using dynamic stress radiographs which serve as an important diagnostic tool for evaluating the status of a motion segment.

Lumbar Spine

The functional examination of the lumbar spine during flexion, extension, and lateral bending is a valuable method to determine pathologic joint conditions. The representative values of the range of motion of the lumbar spine have been provided (Table 5.5A-C).

AP LUMBAR LATERAL FLEXION

The AP lumbar lateral flexion radiograph may be taken on a 14" × 17" film (which will then include the sacrum), a 10" × 12", or an 8" × 10" film. For the best comparison, the film should be taken at the same FFD as the static AP, whether a full spine or sectional exposure was made, and should be at a minimum of 72".

A system of using collimator mounted lead blockers to allow the central ray to remain at the same height as when the full spine film was taken has been devised. The x-ray field is reduced to the size of the film by these external blockers. The collimator is left open along the vertical height. Collimation is closed along the horizontal width to the area of interest. The lead blocker is then placed in the collimator so that only the area of interest is exposed (Fig. 5.32). This ensures that comparative structures are projected onto the film similarly.

Patient Positioning. The patient should be aligned so that the mid sagittal plane is perpendicular to the bucky, and the mid coronal plane is parallel to the film. Depend-
Table 5.5A.
Mean and Range in Degrees for Ranges of Motion of the Lumbar Functional Spinal Units During Flexion-Extension Motion*

<table>
<thead>
<tr>
<th>FSU</th>
<th>Mean</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion-Extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1–L2</td>
<td>12.0</td>
<td>9.0</td>
<td>16.0</td>
</tr>
<tr>
<td>L2–L3</td>
<td>14.0</td>
<td>11.0</td>
<td>18.0</td>
</tr>
<tr>
<td>L3–L4</td>
<td>15.0</td>
<td>12.0</td>
<td>18.0</td>
</tr>
<tr>
<td>L4–L5</td>
<td>17.0</td>
<td>14.0</td>
<td>21.0</td>
</tr>
<tr>
<td>L5–S1</td>
<td>20.0</td>
<td>18.0</td>
<td>22.0</td>
</tr>
</tbody>
</table>


Table 5.5B.
Mean and Range in Degrees for Ranges of Motion of the Lumbar Functional Spinal Units During Lateral Bending*

<table>
<thead>
<tr>
<th>FSU</th>
<th>Mean</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral Bending (One Side)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1–L2</td>
<td>6.0</td>
<td>3.0</td>
<td>8.0</td>
</tr>
<tr>
<td>L2–L3</td>
<td>6.0</td>
<td>3.0</td>
<td>9.0</td>
</tr>
<tr>
<td>L3–L4</td>
<td>8.0</td>
<td>5.0</td>
<td>10.0</td>
</tr>
<tr>
<td>L4–L5</td>
<td>6.0</td>
<td>5.0</td>
<td>7.0</td>
</tr>
<tr>
<td>L5–S1</td>
<td>3.0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>


Table 5.5C.
Mean and Range in Degrees for Ranges of Motion of the Lumbar Functional Spinal Units During Axial Rotation*

<table>
<thead>
<tr>
<th>FSU</th>
<th>Mean</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial Rotation (One Side)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1–L2</td>
<td>2.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>L2–L3</td>
<td>2.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>L3–L4</td>
<td>2.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>L4–L5</td>
<td>2.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>L5–S1</td>
<td>5.0</td>
<td>3.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>


ing on the size of film, different alignment procedures are used. The most important factor is that the patient's entire spine is projected onto the film.

The patient is instructed to flex laterally to the maximum. Ensure that no rotation ($\pm \theta Y$) of the lumbar spine or pelvis has occurred, that the patient's mid sagittal plane is centered and perpendicular to the bucky, and that the patient is positioned so that the lumbar spine in the stressed posture will project onto the film. Appropriate shielding should be used to protect the patient. The exposure should be made during suspended expiration (Fig. 5.33).

NORMAL LUMBAR LATERAL FLEXION

The general outline of the vertebral bodies should maintain constant relationships to one another. The normal coronal coupling pattern of the lumbar spine involves lateral flexion ($\pm \theta Z$) with axial rotation ($\pm \theta Y$). As the lumbar spine is laterally flexed, axial rotation is combined with lateral bending such that the spinous processes rotate towards the ipsilateral side of lateral bend ($+\theta Z$ with $+\theta Y$, and $-\theta Y$ with $-\theta Z$). Rotation ($\pm \theta Y$) proceeds smoothly from the lumbosacral junction upwards as evidenced by progressive migration of the pedicular image.
relative to the general outline of the vertebral body (43) (Fig. 5.34A-B).

**Dysfunctional Lateral Flexion**

A lumbar FSU is considered to be dysfunctional when it exhibits abnormal movement. This movement can be abnormal in quality (coupling patterns) or in quantity (increased or decreased motion). It can be either unilateral or bilateral and can occur along a single axis of motion or along multiple axes of motion. This dysfunctional motion may involve an increase, decrease or complete lack of vertebral body lateral flexion ($\pm \theta Z$) or can involve paradoxical lateral flexion to the opposite side. Rotation ($\pm \theta Y$) may also be affected and can be manifested as increased, decreased, paradoxical, or complete lack of spinous rotation (See Chapter 7). These deficits may occur singularly or in combination.

**Analyzing the AP Lateral Flexion Radiograph**

A standard X-ray pencil is used for the marking of this film. It begins by numbering each segment. Dots are then placed on like points on the right and left of each vertebra. The X axis is determined for each vertebra by connecting these points with a line. The spaces between these lines represent the shape of the disc during lateral flexion.

Rotation is determined by a comparison of the pedicular shadows. The pedicles are compared first right to left and then to those of the vertebra below. The degree of rotation is determined by the shape and position of the pedicles as discussed for the AP static radiograph. Rotation can be checked by placing dots at the far right and left corners of the superior and inferior end-plates. These dots are then connected, the upper right with the lower left, and the upper left with the lower right. The intersection of these lines designates the midpoint of the vertebra. The point of the spinolaminar junction can be compared with this midline to determine the direction of spinous rotation. It is important to understand that the spinous processes are often anomalous making this method suspect (49).

The comparison of stress lateral flexion radiographs to the static film helps to evaluate the static listing and provides additional information regarding the significance of the static misalignment. When the dynamic radiographic findings are in agreement with those on the static film, then treatment may proceed with confidence. If, for example, a lumbar segment is found to be deficient in both $+\theta Z$ and $+\theta Y$ during right lateral bending, and if on static comparison a misalignment of PLI is found, then the chiropractor can proceed with an adjustment of a PLI. A lumbar segment that demonstrated a decreased $+\theta Z$ during right lateral bending and showed a deficit in $-\theta Y$ in left lateral bending would support a static misalignment of PRS. Treatment with an adjunctive thrust can follow (Fig. 5.35A-B). If, however, a lumbar vertebra were
to be viewed in a static misaligned position but during stress evaluation demonstrated normal or hypermobile motion, it would indicate a compensation and is consequently a contraindication for manipulation.

The sacrum can also be evaluated during lateral bending. The sacrum should rotate around the $\pm \theta Y$ axis during lateral flexion, with the sacral ala on the side opposite of the lateral bending rotating posterior. This can be analyzed by measuring the distance between the lateral borders of the sacrum and the center of S2 during lateral flexion. This should be compared to the measurements on the static radiograph and during opposite side lateral bending. If the measurement on the side of lateral flexion does not decrease, then the sacrum can be considered to be fixated in a posterior position (P-L, P-R) on the side of lateral flexion (See Chapter 6).

LUMBAR FLEXION/EXTENSION

The lumbar flexion or extension radiograph may be taken on a 14” X 17” film or on a horizontally placed smaller film. For the best comparison, the FFD should be the same as the static lateral, whether a full spine or sectional view was performed. The FFD should be a minimum of 72”. The central ray can be left in the same position as for the full spine, if external lead blockers are used.

PATIENT POSITIONING FOR LUMBAR FLEXION/EXTENSION

While in the upright posture, the patient should be instructed to assume the desired stressed posture. The doctor should ensure that the entire lumbar spine will be projected onto the film.

The pelvis can be stabilized with a compressive device or the patient’s pelvis can be supported against the bucky. Appropriate shielding should be used. The patient is instructed to remain perfectly still and suspend respiration during the exposure (Fig. 5.36–5.37).

NORMAL LUMBAR FLEXION/EXTENSION

In the sagittal plane, flexion/extension coupling patterns of the lumbar spine consist of rotation about the X axis ($\pm \theta X$) and should not normally involve any anterior or posterior translation ($\pm Z$). Failure of the motion segment in shear indicates disc disruption (See Chapter 2).

During flexion of the lumbar spine, each segment should rotate in a $+\theta X$ direction. There will be a fanning of the spinous processes and an anterior wedging of each IVD. There should be a smooth and even anterior curve with no anterior or posterior displacement (Fig. 5.38A).

During extension, each segment will rotate in a $-\theta X$ direction. There should be an approximation of the spi-
nous processes and a posterior wedging of the IVDs. A smooth and even posterior curve should be produced with no anterior or posterior translation (Fig. 5.38B-C).

ANALYSIS OF DYSFUNCTIONAL LUMBAR FLEXION/EXTENSION RADIOGRAPH

The spine should be evaluated qualitatively because there is not significant agreement as to the quantitative parameters of lumbar flexion or extension. The function of each segment should be compared with the motion of the segments above and below, keeping in mind that flexion and extension decreases incrementally from L5-S1 up through L1-L2. Each segment should be observed for increased or decreased motion, altered axis of rotation and anterior or posterior translation.

During lumbar flexion, if a particular segment does not move in a +θX direction, then it can be considered
to be fixated in a posterior inferior position and is a candidate for an adjustment (Fig. 5.39A-B). If, however, a segment demonstrated excessive $+\theta X$ motion during lumbar flexion, then that FSU would be considered a compensation and is contraindicated for an adjustment.

During lumbar extension, if a segment does not move in a $-\theta X$ direction or exhibits an increase in retrolisthesis, then that FSU is considered fixated and is a candidate for adjustments (70) (Fig. 5.39C and 5.40A-B).

Lumbar flexion/extension studies serve as important confirmation of spinal instability. The motion between segments affected will increase proportionately to the degree of ligamentous and disc damage. In the lateral view, those segments with severe instability may exhibit paradoxical motion when stressed (70).

**Thoracic Spine**

**PATIENT POSITIONING FOR THORACIC LATERAL FLEXION**

**Lateral flexion.** The AP thoracic lateral flexion radiographs should be taken on an 8” × 10”, 10” × 12”, or a 14” × 17” film. The x-ray field is collimated to the area of interest. The FFD should be at least 72” and replicate the FFD of the AP neutral.

The patient is asked to stand with the mid sagittal plane perpendicular to the bucky, chin slightly elevated,

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**Figure 5.39.** A, Dysfunctional radiograph of lumbar sagittal flexion. Note the posterior displaced L5 vertebra. B, Abnormal lumbar flexion. Notice the fixated posterior and inferior L5 vertebra. C, Abnormal lumbar extension. Notice the retrolisthesis at L5.

**Figure 5.40.** A, Neutral position. Notice the posteriorly wedged disc at L5-S1, indicative of a base posterior sacrum (See Chapter 7). B, Abnormal radiograph of lumbar sagittal extension of patient in A. Notice failure of the L5-S1 motion segment to extend ($-\theta X$).
and arms to the sides. The doctor instructs the patient to bend the thoracic spine laterally, ensuring that no lumbar lateral flexion or pelvic rotation occurs. The patient is instructed to hold this position (the palmar surface of the lower hand should be approximating the lateral surface of the ipsilateral knee) and suspend full expiration (Fig. 5.41).

**Rotation.** For rotation, the patient begins in the same static position and then rotates the thorax by bringing a shoulder and/or arm forward, ensuring that the pelvis remains parallel to the bucky (Fig. 5.42).

**ANALYSIS**

**Lateral bending.** The thoracic spine is analyzed primarily during lateral bending and rotation. Lateral flexion of each FSU should occur similarly as in other areas of the spine. When the patient isolates thoracic movement, so that no lumbar lateral flexion occurs, the normal coupling motion involves contralateral spinous rotation during lateral bending.

The spinous processes should rotate in a $+\theta Y$ direction during left lateral flexion and in a $-\theta Y$ direction during right lateral flexion. Rotation should progress as one moves cephalad. The mortise-like configuration of the thoracolumbar zygapophyseal joints severely limits axial rotation (71) (Figs. 5.43, 5.44A-B).

If lateral bending is not isolated to the thoracic spine, then the lower thoracic segments will follow the lumbar pattern of ipsilateral spinous rotation. The upper thoracic segments should follow a contralateral pattern. Generally, this transition occurs at the mid thoracic area.

**Rotation.** If a question involving thoracic rotation remains, it can be evaluated further by inducing thoracic rotation without lateral bending. The spinous processes should move in the same direction as the rotation of the thorax, again progressively, as one moves cephalad (Figs. 5.45–5.46).
**Figure 5.44.** A, Abnormal left lateral bending. Note lack of lateral flexion at T4. An external marker (BBBB) is at the level of a temperature differential. B, Right lateral bending. Note severe dysfunction in lateral flexion (+\(\theta Z\)) of T6 during bending.

**Figure 5.45.** A, Radiograph of near normal thoracic AP axial rotation (\(-\theta Y\)). B, Radiograph of near normal thoracic AP axial rotation (\(+\theta Y\)).
Cervical Spine

The biomechanical functions of the cervical spine include the support of the head, allowance of complex motion, and the protection of neural elements. Support is achieved through ligamentous and muscular forces along with an ingenious set of anatomic structures (33). The resultant structure has the capacity to sustain and attenuate many different loads while allowing a wide range of movements (72).

The functional examination of the cervical spine during flexion, extension, and lateral bending is a valuable method to determine pathologic joint conditions. The representative values of the range of motion of the cervical spine have been provided (Table 5.6A-C).

Table 5.6A.
Mean and Range in Degrees for Ranges of Motion of Cervical Functional Spinal Units During Flexion-Extension Motion

<table>
<thead>
<tr>
<th>FSU</th>
<th>Mean</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0–C1</td>
<td>24.5</td>
<td>9.9</td>
<td>37.4</td>
</tr>
<tr>
<td>C1–C2</td>
<td>15.0</td>
<td>8.0</td>
<td>22.0</td>
</tr>
<tr>
<td>C2–C3</td>
<td>12.0</td>
<td>6.0</td>
<td>17.0</td>
</tr>
<tr>
<td>C3–C4</td>
<td>17.0</td>
<td>10.0</td>
<td>24.0</td>
</tr>
<tr>
<td>C4–C5</td>
<td>21.0</td>
<td>14.0</td>
<td>28.0</td>
</tr>
<tr>
<td>C5–C6</td>
<td>23.0</td>
<td>16.0</td>
<td>31.0</td>
</tr>
<tr>
<td>C7–T1</td>
<td>6.0</td>
<td>4.0</td>
<td>17.0</td>
</tr>
</tbody>
</table>


Table 5.6B.
Mean and Range in Degrees for Ranges of Motion of Cervical Functional Spinal Units During Lateral Bending

<table>
<thead>
<tr>
<th>FSU</th>
<th>Mean</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0–C1</td>
<td>5.0</td>
<td>16.5</td>
</tr>
<tr>
<td>C1–C2</td>
<td>6.7</td>
<td>0.8</td>
</tr>
<tr>
<td>C2–C3</td>
<td>6.0</td>
<td>0.8</td>
</tr>
<tr>
<td>C3–C4</td>
<td>6.0</td>
<td>0.8</td>
</tr>
<tr>
<td>C4–C5</td>
<td>6.0</td>
<td>0.8</td>
</tr>
<tr>
<td>C5–C6</td>
<td>6.0</td>
<td>0.8</td>
</tr>
<tr>
<td>C6–C7</td>
<td>6.0</td>
<td>0.8</td>
</tr>
<tr>
<td>C7–T1</td>
<td>6.0</td>
<td>0.8</td>
</tr>
</tbody>
</table>


Table 5.6C.
Mean and Range in Degrees for Ranges of Motion of Cervical Functional Spinal Units During Axial Rotation

<table>
<thead>
<tr>
<th>FSU</th>
<th>Mean</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0–C1</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>C1–C2</td>
<td>40.5</td>
<td>46.0</td>
</tr>
<tr>
<td>C2–C3</td>
<td>3.0</td>
<td>10.0</td>
</tr>
<tr>
<td>C3–C4</td>
<td>6.5</td>
<td>10.0</td>
</tr>
<tr>
<td>C4–C5</td>
<td>6.8</td>
<td>12.0</td>
</tr>
<tr>
<td>C5–C6</td>
<td>6.9</td>
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<td>C6–C7</td>
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<td>10.0</td>
</tr>
<tr>
<td>C7–T1</td>
<td>2.1</td>
<td>7.0</td>
</tr>
</tbody>
</table>

PATIENT POSITIONING FOR AP CERVICAL LATERAL FLEXION

The cervical lateral bending radiographs should be taken on an 8" x 10" film at the same FFD and central ray height as the neutral AP. The minimal FFD is 72 inches.

The patient is asked to stand with the mid sagittal plane perpendicular to the bucky and aligned with the vertical component of the central ray. The patient is instructed to flex the head laterally, making sure the contralateral shoulder does not rise. Ensure that no rotation ($\pm \theta Y$) or sway has been introduced and that the cervical spine will be projected onto the film. The patient is instructed to suspend respiration and remain perfectly still. A filtration system should be used to protect the patient and improve film quality. The exposure is taken during suspended respiration (Fig. 5.47).

LATERAL FLEXION OF THE CERVICAL SPINE

During lateral flexion, the vertebral bodies should maintain constant relationships to one another. The normal coronal coupling patterns in the lower cervical spine (C2-C7) are attributed to soft tissue tensions as well as the spatial orientations of the facets (43,51). Lateral flexion is limited by the uncinate processes at the end-range.

The normal coupling motion of lateral flexion ($\pm \theta Z$) in the cervical spine is similar to the patterns in the normal thoracic spine. The spinous processes migrate to the convexity of the curve during lateral flexion. Therefore, in right lateral bending ($+\theta Z$), the spinous processes rotate to the left ($-\theta Y$) and in left lateral bending ($-\theta Z$), there is an associated axial rotation of the spinous processes to the right ($+\theta Y$) (73). Rotation ($\pm \theta Y$) should proceed smoothly from the upper thoracic spine evidenced by progresive spinous process migration relative to the general outline of the vertebral body (Fig. 5.48).

Lysell et al. (73) have studied the coupling mechanism of axial rotation occurring simultaneously with lateral flexion. There is a gradual increase in coupling as one moves cephalad:

C2: For every 3° of lateral flexion there is 2° coupled axial rotation (ratio of 2:3)

C7: For every 7.5° of lateral flexion there is 1° coupled axial rotation (ratio of 1:7.5)

Lysell et al. (73) hypothesize that the decrease in axial rotation in the lower cervical spine, is due to facet geometry.

Because of the unique anatomical and physiologic make-up of the upper cervical spine, special consideration must be taken during analysis of this area. Little normative data exist regarding the intricate biomechanics of this region during lateral bending. During lateral flexion of the normal upper cervical spine, there should be little or no side slippage of C1 on C2 (Fig. 5.49A-C). Excessive lateralolisthesis (>4 mm) of this area is a sign of ligamentous damage. Because the lateral atlantoaxial joints have biconvex surfaces, when axial rotation occurs, there is a $-Y$ translation of the atlas. The horizontal plane lines of the atlas and axis should converge on the side of lateral bend.
DYSFUNCTIONAL CERVICAL LATERAL FLEXION

Radiographs of the lower cervical spine are analyzed similarly to other spinal lateral flexion radiographs. Normal coupling action of the cervical spine is taken into consideration. When there is a reduced movement at a motion segment in the cervical spine because of injured tissues, there is often a compensatory increase in the motion of adjacent segments. These compensations may be displayed as misalignments on a static radiograph, and it will be very difficult to differentiate from misaligned fixed segments. It is essential that they be distinguished to determine the proper course of treatment. This can best be done with stress radiographs. If on assuming a stressed posture, the movement of the segment agrees with the static misalignment and demonstrates decreased motion, that FSU is a good candidate to be adjusted. If the segment is shown to be a hypermobile compensation, then manipulation is contraindicated.

If a segment shows decreased motion in both $+\theta Z$ and $-\theta Y$ during right lateral bending, and a check of the static misalignment demonstrates a PRS, then a fixated motion segment would be substantiated and a course of adjutant therapy indicated. A segment that shows a PLI static misalignment and displays a decrease in $+\theta Z$ during right lateral bending and a decrease in $+\theta Y$ during left lateral bending would substantiate the accuracy of the static misalignment. This can provide additional evidence in determining the directional vectors of an adjustment thrust (Fig. 5.50). If, however, the FSU demonstrates hypermobility during a stressed posture and shows no fixation dysfunction, then that segment should not be adjusted regardless of any apparent static misalignment.

Carrick (66) noted that deviations from the normal coupling mechanism in the cervical spine were related to the level of clinical radiculopathy. Aberrances in the coupling mechanism of the FSU of the cervical spine were reduced through chiropractic adjustments, and post-adjustive examination revealed improvements in sensation, motor power, and deep tendon reflexes, as well as symptoms.
PATIENT POSITION FOR CERVICAL FLEXION/EXTENSION RADIOPHGRAPHS

A cervical flexion or extension radiograph should be taken on a 8" × 10" at the same FFD as the neutral AP, a minimum of 72". The patient is instructed to stand with the mid coronal plane perpendicular to the bucky and aligned with the vertical component of the central ray. The patient is instructed to assume the desired stressed position. The doctor must check to ensure that no rotation (±θY) or lateral flexion (±θZ) has been introduced and that the cervical spine will be projected onto the film. A filtration system should be used to protect the patient and improve film quality. The patient is instructed to suspend respiration and remain perfectly still during the exposure (Figs. 5.51-5.52).

CERVICAL FLEXION/EXTENSION ANALYSIS

Sagittal plane dynamic stress studies of the cervical spine offer additional information that the neutral lateral does not. These radiographs allow for visualization of the FSU and aberrations in intersegmental motion and also provide confirmation of ligamentous, IVD, and suspected fracture instabilities (46).

Extension/flexion movements of the cervical spine are similar to those of the lumbar spine and are analyzed accordingly (Fig. 5.53A-B). In the flexion view (+θX), the facet joints and their ligamentous supports are stretched (Fig. 5.54A-B). Damage to these ligaments become more apparent as they are called on to limit the extent of motion. Posterior ligament damage will allow an increase in the posterior height of the IVD and a corresponding decrease at its anterior aspect during motion. The spinous processes will exhibit a "fanning" effect caused by the instability of the posterior spinal ligaments, that exceeds normal fanning. Instability of the transverse ligament is indicated when the ADI increases by 5 mm or more and is not only a contraindication to chiropractic adjustments but also an indication for neurosurgical referral (2,46).
An important additional consideration is the comparison of the occipital-atlanto-axial (OAA) interspaces. The space between the posterior tubercle of atlas and the spinous process of axis should be approximately equal to the interspace between the posterior tubercle of atlas and the occiput. This relationship, although quantitatively changed, should maintain a relative ratio in the neutral lateral, flexion, and extension radiographs. Lack of normal translation may indicate fixation, but excessive motion should be regarded with a great deal of caution, especially in the child, because this area may be relatively less stable because of its anatomic configuration (43).

In the sagittal extension view (−θX), the anterior cervical structures are stretched, while the posterior elements are compressed. Damage to the ALL, the anterior portion of the IVDs, and avulsion fractures of the anterior vertebral bodies may become more visible as increased motion or osseous displacement occurs. The facets are evaluated for proper posteroinferior glide, with associated approximation of the spinous processes (Fig. 5.55).

To complete the analysis of the lateral cervical views, templating of the segments in the neutral, flexed and extended positions may provide evidence of instability. Acetates are used to compare the cervical spine as it translates between the neutral position and the extremes of flexion/extension. The reader is directed to a method developed by Henderson and Dorman (74).

Other useful methods of analysis for the presence of
Posttherapeutic Radiologic Examinations

Posttherapeutic radiologic examinations provide an assessment of the effectiveness of treatment in altering kinesiopathologies. Desired and undesired changes in positional dyskinesia, fixation dysfunction, altered axis of rotation or hypermobility can be monitored through comparative radiography. With the advances in equipment and technology, exposure levels have decreased significantly for radiologic examinations. As the risks decrease, the application of post radiographs becomes more acceptable. The findings from these post radiographs provide information that can affect the clinical management of the patient and thus may be justified when clinical findings indicate the need for reevaluation.

Indications for the Comparative Examination

It is important to only take views that have the potential to provide information that will alter future treatment. The view selection should be based on the most recent physical examination findings and information derived from the initial radiographs. In general, full spine or sectional comparative radiography is justified by the attending physician if such information would alter the course of treatment. Examples of indications include, but are not limited to the following:

1. When clinical examination procedures (e.g. pain questionnaires, motion palpation findings, instrumentation findings, etc.) do not correlate with the information from the most recent radiographic examination;
2. If the patient was initially x-rayed in an acute or antalgic position, since changes in tonicity of the paraspinal musculature would alter the postural configuration of the spinal column;
3. If the patient's clinical symptomatology does not improve within a four to six week period. There may be instances where comparative radiographs would be required prior to this time period. The major determining factor would be if physical findings do not correlate with the initial radiographs. A second chiropractic opinion is often helpful, if the attending physician is contemplating a comparative examination;
4. If there has been the introduction of a foot orthotic (e.g. heel lift) and the physician needs to determine the postural adaptation to the device;
5. There is an alteration in the orthopedic or neurological findings unexplainable without a radiograph. In many instances additional diagnostic tests, such as electronic thermography or electromyography, may be more appropriate for gaining the necessary information critical to case management;
6. There has been a traumatic insult since the initial radiograph;
7. To monitor a potentially progressive scoliosis;
8. To follow a pathological process such as degenerative joint disease, fracture healing or post-traumatic ligamentous laxity or creep;
9. If initial radiographs were not performed in an upright weight-bearing position.
10. To monitor response to treatment in terms of biomechanical parameters, if the information derived from the radiograph is likely to alter case management.

Contraindications for Comparative Examinations

Comparative radiographic examinations should not be performed in the following circumstances:
1. When there is any possibility of pregnancy (unless not performing the procedure would place the mother at risk);
2. In the absence of objective clinical findings indicating the need for comparative examination;
3. When no change in treatment procedures would be anticipated from the examination;
4. When appropriate filtration, shielding and high speed screen/film (e.g. 1200 speed) are not being used.

PATIENT EDUCATION

The radiograph serves as an important aid in educating patients about their spinal condition and how that condition deviates from normal. The old adage "to see is to know, and not to see is to guess," holds for the patient as well as the doctor. Enabling the patient to view the kinesiopathologic components of the vertebral subluxation complex (See Chapter 3) with a proper explanation from the doctor helps the patient understand the important underlying evidence of the condition. This not only helps the patient to appreciate that, like degenerative manifestations themselves, symptomatology is a result of the causative condition and is not the disease itself. This comprehension by the patient tends to foster improved involvement and compliance towards a more complete resolution of the malady beyond the initial symptomatic improvement. This alone is not justification for performing a radiographic examination but can serve as an additional benefit should a radiographic examination be required.

REFERENCES
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The pelvis is the means by which the weight of the erect posture is transferred to the lower limbs. Its shape and function enables the individual to perform a range of activities, such as sedentary sitting and standing, walking and running. These activities distinguish humans from their relatives on the ancestral tree, yet the literature tends to discuss the components of the pelvis in isolation.

There is considerable controversy as to the types of joints that exist in the pelvis, as well as the number of ligaments. In addition, there is debate over joint dysfunction, axes of rotation and translation, unilateral joint dysfunction, short leg syndromes, asymmetry of bones, joint innervation, accessory joints, patterns of pain, and the role of the muscles spanning the joint.

The pelvis has been overlooked by many as a potential site of dysfunction causing low back pain. During the dynasty of the disc, for most of this century, the sacroiliac articulation was virtually ignored. For many years the joint was considered immovable. When Gonstead graduated as a chiropractor in 1923, the pelvis was not considered movable or regarded as a potential site for subluxation. Repeatedly, he observed patients with pain and edema over the sacroiliac joints after falls and lifting strains. By observing and correlating observations with x-ray findings, he developed the concept of pelvic listings to confirm the clinical observation of a sacroiliac subluxation. Indeed, Gonstead was the first to describe pelvic listings and the adjustments for their correction.

The following presentation will summarize the generally accepted view of the pelvis anatomically, functionally and clinically. More importantly, it will outline a thorough approach to what is regarded by many as the most common site for the origin of back pain.

ANATOMY

The pelvis is made up of the sacrum, two innominate bones, the coccyx, and connective tissues. It serves as a support for the vertebral column and as such, is strongly constructed to withstand the compressive forces of the trunk via the fifth lumbar vertebra. The pelvis supports and protects to some degree the viscera of the region, such as the uterus, ovaries and lower intestines, and acts as the means by which the trunk articulates with the lower limbs, thus absorbing the ground reaction forces via the acetabulae (1). The pelvis includes all structures between the fifth lumbar vertebra and the femoral heads (2) (Fig. 6.1).

In a normal fully functional pelvis, the trunk weight passes through the body of the fifth lumbar vertebra (L5) via the alae of the sacrum to the acetabulum. Ground reaction forces are transferred via each femur to its acetabulum, with some of the force passing horizontally to the pubic ramus, meeting at the pubic symphysis (3,4). The ability of the pelvis to function in this manner and provide mobility for upright movements, depends on the strength and stability of both sacroiliac joints and the pubic symphysis. The latter is universally regarded as an amphiarthrodial joint where the two osseous surfaces are connected by an elastic fibrocartilage. This allows very slight movement in all directions, depending on the elasticity of the cartilage (1,2,5).

Sacroiliac Joint

The sacroiliac joint has undergone a checkered history of description. It has been described as being amphiarthrodial and diarthrodial. The diarthrodial joint is a true synovial joint. These joints possess a cavity and are specialized to permit movement (5).

Figure 6.1. A, The trunk weight passes through the body of the fifth lumbar via the alae of the sacrum to the acetabulum. B, Ground reaction forces are transferred by each femur to its acetabulum. C, Some of the force passes horizontally to the pubic ramus, meeting at the pubic symphysis. Modified from Kapandji IA. The physiology of the joints. Vol 3. Edinburgh: Churchill Livingstone 1978:57.