Guide to Image Analysis

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Introduction to Image Analysis

Why do x-ray technologists need to analyse radiographs?

The analysis of images is a crucial step in which an x-ray technologist partakes within a radiographic procedure. Radiographers must always ask themselves – does the image represent the actual anatomy as much as possible? The goal of each projection should be to truly represent anatomical relationships and to answer the query from the ordering physician.

However, this is not always possible. There are many limitations outside of a radiographer's control that can affect the desired projection. An acceptable image is not necessarily optimal. A radiographer can use their knowledge and judgement to decide if a sub-optimal image meets parameters of acceptability within these guidelines (Martensen, 2020 p. 66):

- Standards of the facility
- Conditions of the patient (cooperative or combative, limited mobility, pain, etc.)
- Conditions of the exam space (such as a room on a unit)
- Reason(s) for exam – even though the image is not optimal, has the suspected pathology been proven or disproven?
- Post-processing – does altering the window or algorithm display the pertinent VOI?

Using these guidelines, the radiographer can make the decision to accept the sub-optimal image or perform a repeat exposure. Long (2019) states that "individual differences [between patients] must be considered when the quality of the radiograph is judged". Before the decision is made to repeat a projection, consideration must also be made for the increased dose and resources of each repeat (time, cost of supplies and use of equipment) (Martensen, 2020 p. 67).

Image analysis does not follow a random path to accepting or rejecting an image. With knowledge of anatomical relationships, pathology, beam geometry and digital processing, radiographers are expected to make educated decisions on the acceptability of each projection. Using judgement for the feasibility of an optimal image, in conjunction with theoretical knowledge, radiographers can make decisions that are reasonable and justifiable.

Table 1.1 on the following page shows the questions within specific criteria that will lead radiographers to make these decisions.

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Image Analysis Criteria

Table 1.1

Part and Projection 1. Projection 2. Part
Centering and Required Structures 1. Where should the CR be centered? Where is the CR actually centered in this image? 2. What structures are required? Are there just enough structures included, too many, or not enough? 3. Describe any corrective actions if there was too many or not enough structures included.
Collimation 1. How many sides of collimation are seen? 2. Is the collimation open just enough, too much, or not enough?
Markers and Annotations 1. What markers should be included? Are required markers visible on this image? 2. Describe any corrective actions if required markers are not visible.
Positioning 1. Describe how the structures *should* look on this projection. 2. Describe, and prove, any positioning errors relative to these movements, where applicable: • Rotation • Tilt (sagittal plane or coronal plane tilt) • Flexion/Extension • Elevation/Depression • CR angulation 3. If applicable, prove how you differentiated similar looking anatomy (e.g. lateral talar dome from medial talar dome). 4. Describe any corrective actions.
Image Quality 1. Is the image within acceptable EI parameters? 2. Was the kV used within acceptable parameters? 3. Was the mAs used what you would expect, considering patient factors? 4. Does the displayed image contrast allow each structure to be distinct from another (e.g. bone vs. ST vs. air)? 5. Has the image contrast been affected by image noise? 6. Describe any corrective actions to increase image quality (technique factors, grids, centering, collimation, etc.)
Foreign Bodies and Pathologies 1. Describe any visible foreign bodies, artifacts or pathologies. 2. Describe corrective actions, if any.

Analyzing Digital Image Quality

CONTRAST

Subject Contrast

Subject contrast refers to how anatomical tissues of varying densities attenuate the beam to varying degrees. These differences in absorptive qualities of the tissues will thus create varying intensities of the remnant beam, referred to as differential absorption and the resultant differences in shades of gray of the image. It is important to note here that as kV increases, penetration increases, and differential absorption of x-ray photons decreases. A decrease in differential absorption decreases the ability to demonstrate the variances in tissue as different shades of gray on the image.

Image Contrast (Radiographic Contrast)

Image contrast refers to the differences of brightness levels between two adjacent structures visualized on a radiograph. Image contrast should be optimal so that one structure can be distinctly seen as separate from another structure.

- A high contrast image does not have many shades of gray seen on the spectrum between black and white. The difference from one gray shade to the next is distinct and probably easily discernable (Fig. 1.1).

- A low contrast image has many shades of gray seen on the spectrum between black and white. The difference from one gray shade to the next may not be easily distinguishable (Fig. 1.2).

Contrast Resolution

Contrast resolution refers to the inherent ability of the imaging system to display different shades of gray. The greater the contrast resolution of the system, the greater its ability to discern differences in attenuation of tissue, resulting in the more available shades of gray to display on the monitor.

Fig. 1.1 High contrast, not many shades of gray are displayed between the extremes of black and white.

Fig. 1.2 Low contrast, many shades of gray displayed on the spectrum between black and white.

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QUANTUM NOISE (QUANTUM MOTTLE)

Quantum noise or mottle refers to the grainy or random pattern projected onto an image (Fig. 1.3). This occurs when there is underexposure to the IR from an insufficient amount of photons in the remnant beam. Noise will obscure information on the image, thus affecting the contrast resolution. Deficits to image quality from noise cannot be improved with post processing.

- Presence of noise necessitates an increase in technical factors
  - Increase kV if cortical outlines of densest structures are not distinguishable.
  - Increase mAs if cortical outlines of densest structures are distinguishable.

Fig. 1.3

Source: Martensen, p. 54

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HISTOGRAMS

Histograms are graphs representing pixel brightness values and how frequently those values occur on a given digital image. S_{min} on the histogram represents the brightest useful gray shade value. S_{max} represents the darkest useful gray shade value (Fig. 1.4).

Source: Martensen, p. 41

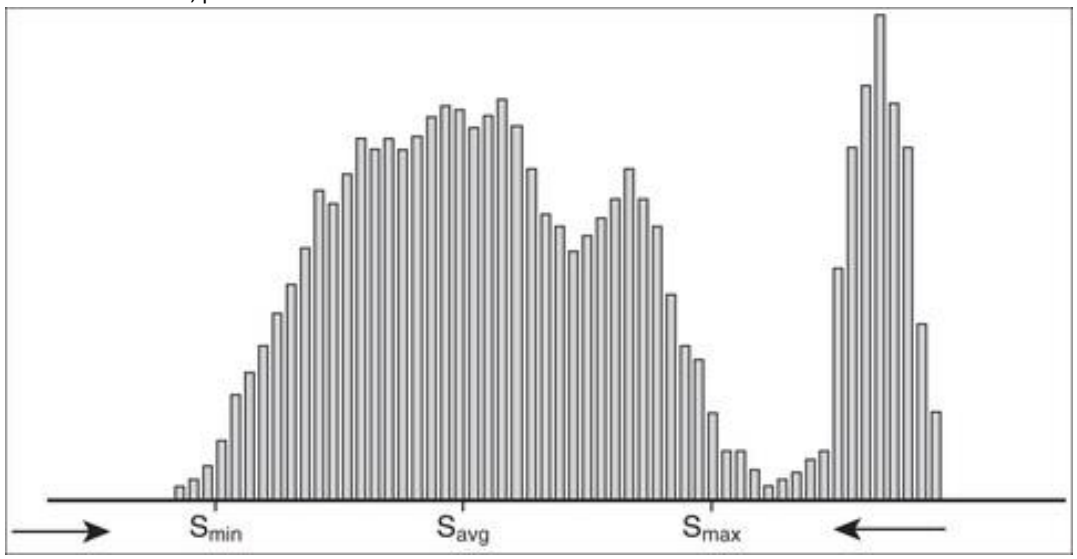

Fig. 1.4 An example of an image histogram where S_{min} represents the brightest shade of gray that is useful to the image, and S_{max} represents the darkest shade of gray that is useful to the image. The spike on the right side of the histogram represents the area around the VOI where there is no attenuation by tissues, therefore creating a high frequency of black pixels seen on the image around the anatomy.

LOOKUP TABLES (LUTs) AND HISTOGRAM ANALYSIS

LUTs are histograms stored in the computer for each body part, for ideal patients under ideal conditions. The computer will analyze the obtained image histogram and automatically rescale to align with histogram in LUT for that part before the image is displayed. For example, if the obtained histogram would display pixel values that are too bright, the computer algorithm will rescale the pixel values to display a darker image. If the obtained histogram and LUT are too dissimilar, the algorithm will not be able to realign the obtained histogram to the LUT. Inability to realign the histogram may warrant an image repeat.

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EXPOSURE INDICATOR (EI)

The EI is a numerical value that indicates the median gray shade value of the image, which is at the midpoint of the histogram. When the histogram is ideal, the midpoint represents the ideal amount of exposure to the image. This is referred to as the target EI. The goal is to produce an image that is as close to the target EI value as possible. However, EI values may deviate from the target value within a given range and still result in an acceptable image. This is referred to as the EI range. Since the displayed EI is based on the obtained histogram, the EI is only a reliable indicator when no histogram analysis errors have occurred.

HISTOGRAM ANALYSIS ERRORS

Various poor positioning procedures may cause the obtained histogram to misshapen (too wide, more to the left or more to the right). When the histogram is misshapen, a histogram analysis error will occur and the displayed EI will be unreliable. Histogram analysis errors may occur when:

DR and CR:

- **Centering point** is incorrect and includes additional anatomy or too much "black space" around volume of interest (VOI).
- **Collimation** is too open and includes additional anatomy or too much "black space" around volume of interest.
- **Scatter** on the image is excessive.
- **Part selection** from protocol menu on the workstation or reader is incorrect.

CR Only:

- **Less than 30%** of cassette is exposed.
- **VOI** is not centered to the cassette.
- **Collimation borders** are not equal distances from the edge of the cassette.
- **More than one projection** is exposed on a single cassette.
- **Background radiation fogging** has occurred on the cassette.

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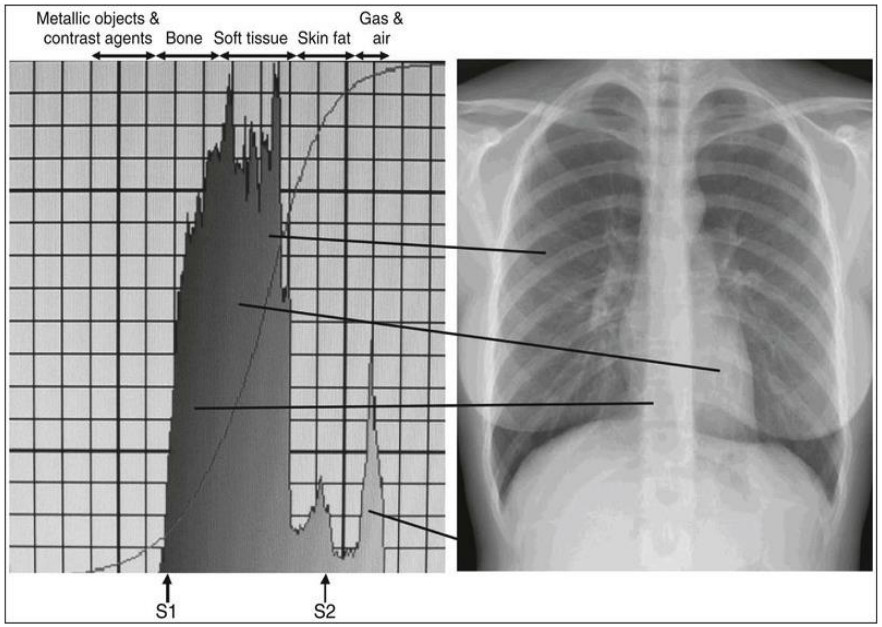

Fig. 1.5 PA Chest projection with an optimal histogram.

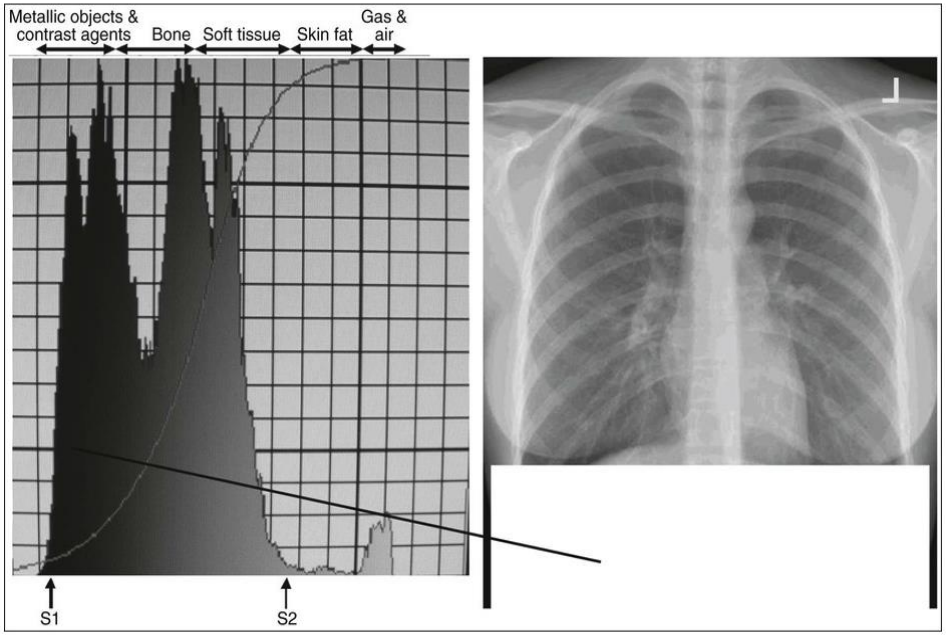

Fig. 1.6 PA Chest projection, using the same technique as the histogram on the left, but collimation includes lead apron around patient's waist. Obtained histogram is wider than optimal. Resultant EI would therefore be unreliable (not indicative of exposure to patient/IR or image quality).

In summary, when the Exposure Indicator is outside of the acceptable range, poor positioning procedures should be considered as the cause before deciding if there is a need to alter technical factors. In other words, it may be possible that factors other than the kV or mAs could be changed to optimize the EI and improve image quality. Once it can be verified all positioning procedures were properly executed, then a change in technical factors would most likely optimize the Exposure Indicator and improve image quality.

Chapter Source: Martensen, Chapters 1 and 2

kV Range Chart (for adult patients, using digital systems)

	kV Range	
Part	**Martensen** (5th ed.)	**Lampignano** (10th ed.)
Finger/Thumb/Hand	55-65	
Wrist	65-70	AP: 55-65 Obl and Lat: 60-70
Forearm/Elbow	70-75	65-75
Humerus	75-85	70-85
Shoulder Girdle	75-85	70-85
Toe	55-60	50-65
Foot	60-70	AP: 55-65 Obl and Lat: 60-70
Ankle	60-75	
Axial Calcaneus	70-75	65-75
Tib/Fib	70-80	
Knee	70-85 (with grid)	65-80 (depending on with or without grid)
Femur	80-85	75-85
Pelvic Girdle/Hip	80-85	80-90 X-table: 80-95
Cranium	80-85	75-95 Lat: 70-85 Towne: 75-90
Mandible/Sinuses/Facial Bones	75-85 Nasal bones: 60-70	70-85 Nasal bones: 65-80
Cervical Spine	75-85	70-85
Swimmer's	80-95	75-95
Thoracic Spine	80-90	AP: 75-90 Lat: 80-95
Lumbar Spine	AP and Obl: 85-95 Lat and Spot: 90-100	AP and Obl: 75-90 Lat: 80-90 Spot: 85-95

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	kV Range	
Part	**Martensen** (5th ed.)	**Lampignano** (10th ed.)
Sacrum	AP: 85-90 Lat: 90-100	AP: 75-90 Lat: 85-95
Coccyx	AP: 80-85 Lat: 85-90	AP: 75-85 Lat: 85-95
Chest	110-125	
Abdomen	70-80	70-85

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Glossary of Terminology, Acronyms, and Abbreviations

Anatomic Position
Upright position with palms, head and tops of feet facing forward

Anterior
Front of patient as viewed from the front, including the palms of the hands and the tops of the feet. Also known as the ventral aspect. (Tops of the feet are also called the dorsal or ventral aspect.)

Anteroposterior (AP)
Projection that refers to the path of a beam that enters the anterior aspect and exits the posterior aspect

ASIS
Anterior Superior Iliac Spine

Axial Plane
Plane dividing the body into inferior and superior parts. Also known as transverse plane or horizontal plane.

Axial Projection
A projection which uses a CR angle of at least 10^{o} along the longitudinal axis of the patient

Caudad/Caudal
Toward the foot of the body

Cephalad/Cephalic
Toward the head end of the body

Coronal Plane
Longitudinal plane dividing the body into anterior and posterior parts

CR
Central Ray: the centermost portion of the x-ray beam; the portion of the x-ray beam with the least divergence

DIP
Distal Interphalangeal

Distal
Away from the source (source is usually the trunk)

Dorsal
Back of the patient as viewed from behind, including the backs of the hands. Note that the dorsal aspects of the feet refers to the soles of the feet.

Extension
Movement that increases the inside angle of the joint

Flexion
Movement that decreases the inside angle of the joint

GT
Greater Trochanter

Horizontal Plane
Plane dividing the body into inferior and superior parts. Also known as transverse plane or axial plane.

Inferior
Closer to the feet

Inferosuperior
Projection that refers to the path of a beam that enters the inferior aspect and exits the superior aspect

IP
Imaging Plate or Interphalangeal

IR
Image Receptor: device that captures the x-ray beam that exits the patient

LAO
Left Anterior Oblique: body position where the patient's left anterior side is obliqued and closest to the IR

Lateral
Away from the median plane

Lateromedial
Projection that refers to the path of a beam that enters the lateral aspect and exits the medial aspect

LCM
Lower Costal Margin

LPO
Left Posterior Oblique: body position where the patient's left posterior side is obliqued and closest to the IR.

LT
Lesser Trochanter

MC
Metacarpal

MCP
Metacarpophalangeal or Mid-Coronal Plane

Medial
Towards the median plane.

Median Plane
Longitudinal plane dividing the body into equal left and right parts. Also known as the mid-sagittal plane.

Mediolateral
Projection that refers to the path of a beam that enters the medial aspect and exits the lateral aspect

MQM
McQuillen-Martensen textbook

MSP
Mid-Sagittal Plane. Also known as the median plane.

MT
Metatarsal

Oblique Plane
Any plane not parallel to a coronal, sagittal or axial plane

Palmar
The palms of the hands, also called the anterior aspect of the hands

Plantar
The soles of the feet, also called the posterior aspect of the feet

PIP
Proximal Interphalangeal

Posterior
Back of the patient as viewed from behind, including the backs of the hands and the soles of the feet.

Posteroanterior (PA)
Projection that refers to the path of a beam that enters the posterior aspect and exits the anterior aspect.

Proximal
Toward the source (source is usually the trunk).

PS
Pubic Symphysis

RAO
Right Anterior Oblique: body position where the patient's right anterior side is obliqued and closest to the IR

Rotation
Movement in which the part turns around its longitudinal axis

RPO
Right Posterior Oblique: body position where the patient's right posterior side is obliqued and closest to the IR

Sagittal Plane
Longitudinal plane dividing the body into left and right parts

SI
Superimposed

ST
Soft Tissue

Superior
Closer to the head end of the body

Superoinferior
Projection that refers to the path of a beam that enters the superior aspect and exits the inferior aspect

Tilt
Movement where there is a slant of the longitudinal axis of the part

Transverse Plane
Plane dividing the body into inferior and superior parts. Also known as horizontal plane or axial plane.

Ventral
Front of patient as viewed from the front, including the palms of the hands and the tops of the feet. Also known as the anterior aspect. (Tops of the feet are also called the dorsal and anterior aspects.)

Volar
The palms of the hands or the soles of the feet. Also known as the anterior aspect of the hands or the posterior aspects of the feet.

VOI
Volume of Interest (or anatomy of interest).

Source: Lampignano, J

Positioning Evaluation Section

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UPPER EXTREMITY – FINGER

Part	Projection	CR	Optimal	Error Assessments	Source
FINGER	PA	No angle, vertical beam. Centered at PIP to include ½ MC to distal ends of phalanges.	**Rotation** ● Phalanges demonstrate equal concavity and ST at mid-shaft **Finger Extension** ● IP joints open ● Phalanges not distorted	**External rotation** ● Phalanges more concave on lateral aspect than medial aspect ● More ST demonstrated on lateral aspect than medial aspect **Internal rotation** ● Phalanges more concave on medial aspect than lateral aspect ● More ST demonstrated on medial aspect than lateral aspect **Fingers not fully extended** ● IP joints closed	MQM pg. 161-165
	Oblique (external oblique)		**Rotation** ● Phalanges more concave on lateral (or palmar) aspect than medial (or dorsal) aspect ● Twice as much ST on lateral (or palmar) aspects of phalanges than medial (or dorsal) **Finger Extension** ● IP joints open ● Phalanges not distorted	**Over rotation (externally)** ● Medial (or dorsal) aspect of phalanges almost straight ● More than twice the ST on the lateral (or palmar) aspects of phalanges than medial **Under rotation (externally)** ● Concavity more equal on medial (or dorsal) and lateral (or palmar) aspects of phalanges ● Less than twice the ST on the lateral (or palmar) aspect of phalanges than medial (or dorsal) **Fingers not fully extended** ● IP joints closed	MQM pg. 165-168

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Part	Projection	CR	Optimal	Error Assessments	Source
FINGER	Lateral	No angle, vertical beam. Centered at PIP to include ½ MC to distal ends of phalanges.	**Rotation** ● Dorsal aspects of phalanges straight (or slightly convex) while anterior aspects concave ● Heads of each phalanx SI ([1]) **Elevation/Depression (finger parallel to IR)** ● IP joints open ● Phalanges not distorted	**Posterior rotation** ● 2nd MC head posterior to other MC heads ([1]) **Anterior rotation** ● 2nd MC head anterior to other MC heads ([1]) **Finger depressed (dropped towards IR)** ● IP joints closed	MQM pg. 168-170

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UPPER EXTREMITY – HAND

Part	Projection	CR	Optimal	Error Assessments	Source
HAND	PA	No angle, vertical beam. Centered at 3rd MCP joint, to include distal 1" of forearm to distal ends of phalanges.	**Rotation** ● Equal concavity at midshafts of phalanges and MCs 2-5 ● Distance between MC heads is equal **Elevation/Depression (finger parallel to IR)** ● IP joint spaces open ● Phalanges not distorted	**External rotation** ● MCs and phalanges demonstrate more concavity and ST on lateral aspects than medial aspects **Internal rotation** ● MCs and phalanges demonstrate more concavity and ST on medial (or dorsal) aspects than lateral (or palmar) aspects **Fingers depressed (dropped towards IR)** ● IP joint closed	MQM pg. 179-182
	Oblique		**Rotation** ● Lateral (or palmar) aspects of phalanges and MCs 2-5 more concave than medial (or dorsal) aspects ● Heads of MCs 3-5 slightly SI ● Small space between MC 4 and 5 ● 2x ST demonstrated on lateral (or palmar) side than medial (or dorsal) side **Elevation/Depression (finger parallel to IR)** ● IP joint spaces open ● Phalanges not distorted	**Over rotation** ● More SI of heads of MCs 3-5 ● Less space between MC 4 and 5 ● Phalanges demonstrate more than twice as much ST on lateral side than medial side **Under rotation** ● Less SI of heads of MCs 3-5 ● More space between MC 4 and 5 ● Phalanges demonstrate less than 2x ST on lateral (or palmar) side than medial (or dorsal) side **Fingers depressed (dropped towards IR)** ● IP joints closed	MQM pg. 182-185

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Part	Projection	CR	Optimal	Error Assessments	Source
HAND	Lateral	No angle, vertical beam. Centered at 3rd MCP joint, to include distal 1" of forearm to distal ends of phalanges.	**Rotation** ● MCs 2-5 SI **Elevation/Depression (finger parallel to IR)** ● IP joint spaces open ● Phalanges not distorted	**Posterior rotation** ● MC 2 posterior to other MCs **Anterior rotation** ● MC 2 anterior to other MCs **Fingers depressed (dropped towards IR)** ● IP joints closed	MQM pg. 185-189

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UPPER EXTREMITY – WRIST

Part	Projection	CR	Optimal	Error Assessments	Source
WRIST	PA	No angle, vertical beam. Centered at mid-carpals to include distal ¼ of forearm to ½ MC.	**Rotation** ● Radioulnar joint is open ● Equal concavity at midshafts of MCs 2-5 ● Minimal SI of MC bases **Elevation/Depression** ● Distal posterior radial margin ¼" distal to anterior margin	**External rotation** ● Lateral aspects of MCs more concave than medial aspects **Internal rotation** ● Medial aspects of MCs more concave than lateral aspects **Wrist higher than elbow** ● Distal posterior radial margin less than ¼" distal to anterior margin **Wrist lower than elbow** ● Distal posterior radial margin more than ¼" distal to anterior margin	MQM pg. 189-196
	Oblique		**Rotation** ● Small space between 4th and 5th MC **Elevation/Depression** ● Distal posterior radial margin ¼" distal to distal anterior margin	**Over rotation** ● Smaller space between the 4th and 5th MC **Under rotation** ● Larger space between the 4th and 5th MC **Wrist higher than elbow** ● Distal posterior radial margin less than ¼" distal to anterior margin **Wrist lower than elbow** ● Distal posterior radial margin more than ¼" distal to anterior margin	MQM pg. 196-200
	Lateral		**Rotation** ● Distal radius and ulna SI ● Anterior aspects of scaphoid and pisiform aligned **Elevation/Depression** ● Distal aspects of scaphoid and pisiform aligned	**Posterior rotation** ● Radius posterior to ulna and scaphoid posterior to pisiform **Anterior rotation** ● Radius anterior to ulna and scaphoid anterior to pisiform **Wrist higher than elbow** ● Scaphoid proximal to pisiform **Wrist lower than elbow** ● Scaphoid distal to pisiform	MQM pg. 200-207

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UPPER EXTREMITY – ELBOW

Part	Projection	CR	Optimal	Error Assessments	Source
ELBOW	AP	No angle, vertical beam. Centered at elbow joint to include distal ¼ of humerus to proximal ¼ of forearm.	**Rotation** ● 1/8th of radial head SI on ulna ● Small amount of radial tuberosity SI on ulna **Elbow Extension** ● Elbow joint is open ● Olecranon is in fossa	**External rotation** ● Less SI of radial head and radial tuberosity on ulna **Internal rotation** ● More SI of radial head and radial tuberosity on ulna **Elbow flexion with humerus in contact** ● Elbow joint closed ● Forearm distorted ● Olecranon out of fossa **Elbow flexion with forearm in contact** ● Elbow joint open ● Humerus distorted ● Olecranon out of fossa	MQM pg. 224-229
	External Oblique		**Rotation** ● Radius free of SI from ulna **Elbow Extension** ● Elbow joint space open ● Olecranon is in fossa	**Under rotation** ● Radial head still SI on ulna **Over rotation** ● Coronoid process starts to SI on radial head **Elbow flexion with humerus in contact** ● Elbow joint closed ● Forearm distorted ● Olecranon out of fossa **Elbow flexion with forearm in contact** ● Elbow joint open ● Humerus distorted ● Olecranon out of fossa	MQM pg. 229-234

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Part	Projection	CR	Optimal	Error Assessments	Source
ELBOW	Lateral	No angle, vertical beam. Centered at elbow joint to include distal ¼ of humerus to proximal ¼ of forearm.	**Shoulder and elbow in the same horizontal plane (forearm rotation)** ● Anterior aspects of radial head and coronoid aligned ● Distal surfaces of capitulum and trochlea SI **Wrist and elbow in the same horizontal plane (humerus rotation)** ● Proximal aspects of radial head and coronoid aligned ● Anterior surfaces of capitulum and trochlea SI	**Elbow lower than shoulder** ● Anterior aspect of radial head posterior to coronoid (more SI on coronoid/ulna) ● Capitulum more distal than trochlea **Elbow higher than shoulder** ● Anterior aspect of radial head anterior to coronoid (less SI on coronoid/ulna) ● Capitulum more proximal than trochlea **Wrist higher than elbow** ● Proximal aspect of radial head proximal to coronoid ● Capitulum more posterior than trochlea **Wrist lower than elbow** ● Proximal aspect of radial head distal to coronoid ● Capitulum more anterior than trochlea	MQM pg. 234-241 MQM pg. 217-223

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UPPER EXTREMITY – HUMERUS

Part	Projection	CR	Optimal	Error Assessments	Source
HUMERUS	AP	No angle, horizontal beam. Centered mid-humerus to include shoulder and elbow joints.	**Rotation** ● Greater tubercle demonstrated in profile laterally ● Lesser tubercle demonstrated approximately in the middle of the humeral head ● Medial and lateral humeral epicondyles demonstrated in profile ● Approx. 1/8 of the radial head is SI on the ulna	**Internal rotation** ● Greater tubercle and humeral epicondyles not in profile ● More than 1/8 of radial head SI on ulna **External rotation** ● Greater tubercle and humeral epicondyles not in profile ● Less than 1/8 of radial head SI on ulna	MQM pg. 245-248
	Lateral		**Rotation** ● Lesser tubercle demonstrated in profile medially ● Anterior aspects of capitulum and trochlea aligned (or very close to)	**Internal rotation** ● Capitulum demonstrated anterior to trochlea **External rotation** ● Capitulum demonstrated posterior to trochlea **use the geometry of the divergent ray to distinguish the capitulum from the trochlea**	MQM pg. 249-253

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SHOUDLER GIRDLE – SHOULDER JOINT

Part	Projection	CR	Optimal	Error Assessments	Source
SHOULDER	AP	No angle, horizontal beam. Centered at superior scapular body to include from clavicle to proximal ⅓ humerus and scapula.	**Rotation** ● Medial end of clavicle next to lateral border of spine **Coronal plane tilt** ● Superior scapular angle SI on mid-clavicle	**Rotation towards affected side** ● Medial end of clavicle further away from spine **Rotation away from affected side** ● Medial end of clavicle SI on spine **Anterior coronal tilt** ● Superior scapular angle superior to mid-clavicle **Posterior coronal tilt** ● Superior scapular angle inferior to mid-clavicle	MQM pg. 255-261
	AP Oblique (Grashey)	No angle, horizontal beam. Centered at shoulder joint to include from lateral clavicle to proximal humerus.	**Rotation** ● 1/3 of coracoid SI on humeral head ● Anterior and posterior aspects of glenoid SI ● Shoulder joint open **Coronal plane tilt** ● Superior aspect of coracoid aligned to superior aspect of glenoid	**Over rotation** ● More than 1/3 of coracoid SI on humeral head **Under rotation** ● Less than 1/3 of coracoid SI on humeral head **Posterior coronal tilt** ● Coracoid superior to glenoid **Anterior coronal tilt** ● Coracoid inferior to glenoid	MQM pg. 269-272

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Part	Projection	CR	Optimal	Error Assessments	Source
SHOULDER	Transcapular "Y"	No angle, horizontal beam. Centered at mid-scapular body to include entire scapula.	**Rotation** ● Medial and lateral scapular borders SI **Coronal plane tilt** ● Superior scapular angle SI on clavicle	**Over rotation** ● Lateral border of scapula closer to ribs than medial border **Under rotation** ● Medial border of scapula closer to ribs than lateral border **Anterior coronal tilt** ● Superior scapular angle superior to clavicle **Posterior coronal tilt** ● Superior scapular angle inferior to clavicle	MQM pg. 273-278
	Inferosuperior Axillary	30°-35° medially (with 90° abduction), centered at humeral head to include entire coracoid to proximal ¼ of humerus.	**CR angle/Patient lean over IR** ● Base of coracoid (also superior aspect of glenoid) aligned with inferior aspect of glenoid ● Shoulder joint open	**CR angle from patient too large or patient leaning over too far** ● Base of coracoid lateral to inferior aspect of glenoid **CR angle from patient too small or patient not leaned over enough** ● Base of coracoid medial to inferior aspect of glenoid	MQM pg. 261-268
	Superoinferior Axillary	Generally no beam angle if patient can sufficiently abduct to get the shoulder joint on the IR.			

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SHOUDLER GIRDLE – CLAVICLE

Part	Projection	CR	Optimal	Error Assessments	Source
CLAVICLE	AP	No angle, horizontal beam. Centered at mid-clavicle.	**Rotation** ● Medial end of clavicle next to lateral border of spine **Coronal plane tilt** ● Superior scapular angle SI on mid-clavicle	**Rotation towards affected side** ● Medial end of clavicle further away from spine **Rotation away from affected side** ● Medial end of clavicle SI on spine **Anterior coronal tilt** ● Superior scapular angle superior to mid-clavicle **Posterior coronal tilt** ● Superior scapular angle inferior to mid-clavicle	MQM pg. 285-287
	AP Axial	30°-35° cephalic. Centered at mid-clavicle.	**Rotation** ● Medial end of clavicle next to lateral border of spine **CR Angle** ● Medial end of clavicle SI over ribs 1-3	**Rotation towards affected side** ● Medial end of clavicle further away from spine **Rotation away from affected side** ● Medial end of clavicle SI on spine **Not enough cephalic angle** ● Medial end of clavicle lower than ribs 1-3	MQM pg. 287-288

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LOWER EXTREMITY – FOOT

Part	Projection	CR	Optimal	Error Assessments	Source
FOOT	AP	10º - 15º towards the heel. Centered at 3rd MT base to include distal calcaneus to distal phalanges.	**Rotation** ● ⅓ of talus SI on calcaneus ● Approx. ½ MT bases 2-5 SI on each other ● Joint space between 1st and 2nd cuneiform open	**External rotation** ● More than ⅓ of talus SI on calcaneus ● MT bases 2-5 more SI on each other ● Joint space between 1st and 2nd cuneiform closed **Internal rotation** ● Less than ⅓ of talus SI on calcaneus ● MT bases 2-5 less SI on each other ● Joint space between 1st and 2nd cuneiform closed	MQM pg. 312-317
	Oblique	No angle, vertical beam. Centered at 3rd MT base to include calcaneus to phalanges.	**Rotation** ● Cuboid free of SI ● MT heads almost free of SI, or slightly SI ● Sinus tarsi and 5th tuberosity demonstrated	**Over rotation** ● Cuboid not free of SI ● MT heads more SI **Under rotation** ● Cuboid not free of SI ● MT heads less SI	MQM pg. 317-321

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Part	Projection	CR	Optimal	Error Assessments	Source
FOOT	Lateral	No angle, vertical beam. Centered at distal tarsals to include distal 1" of lower leg and calcaneus to phalanges	**Rotation** ● Talar domes SI anteroposteriorly ● Distal fibula SI on posterior half of tibia **Elevation/Depression** ● Talar domes SI inferosuperiorly ● About ½ of cuboid demonstrated ● Distal fibula ¼" distal to distal tibia	**External rotation** ● Talar domes not SI anteroposteriorly ● Distal fibula posterior to tibia **Internal rotation** ● Talar domes not SI anteroposteriorly ● Distal fibula on anterior portion of tibia **Foot depressed lower than knee** ● Medial talar dome inferior to lateral talar dome ● Less than ½ of cuboid demonstrated ● Distal fibula less than ¼" distal to distal tibia **Foot elevated higher than knee** ● Medial talar dome superior to lateral talar dome ● More than ½ of cuboid demonstrated ● Distal fibula more than ¼" distal to distal tibia	MQM pg. 321-333

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LOWER EXTREMITY – ANKLE

Part	Projection	CR	Optimal	Error Assessments	Source
ANKLE	AP	No angle, vertical beam. Centered at ankle joint to include distal ¼ of lower leg to talus	**Rotation** ● ½ distal fibula SI on tibia	**External rotation** ● More than ½ fibula SI on tibia **Internal rotation** ● Less than ½ fibula SI on tibia	MQM pg. 341-345
	Oblique		**Rotation** ● ¼ distal fibula SI on tibia ● Medial and lateral mortise open **Dorsiflexion** ● Lateral malleolus free of SI from calcaneus	**Over rotation** ● Less than ¼ distal fibula SI on tibia **Under rotation** ● More than ¼ distal fibula SI on tibia **Inadequate dorsiflexion** ● Calcaneus SI on lateral malleolus	MQM pg. 345-350
	Lateral	No angle, vertical beam. Centered at ankle joint to include distal ¼ of lower leg to calcaneus	**Rotation** ● Talar domes SI anteroposteriorly ● Distal fibula SI in posterior half of tibia ● Medial and lateral subtalar joints SI or slightly touching (^{2}) **Foot Elevation/Depression** ● Talar domes SI inferosuperiorly ● ½ of 5th MT SI on 4th MT (^{2}) ● ½ of cuboid free of SI ● ¼" of distal fibula distal to distal tibia	**External rotation** ● Talar domes separated anteroposteriorly ● Distal fibula posterior to tibia ● Subtalar joints more separated anteroposteriorly and sinus tarsi starts to be demonstrated (^{2}) **Internal rotation** ● Talar domes separated anteroposteriorly ● Distal fibula on anterior portion of tibia ● Subtalar joints more SI (^{2}) **Foot lower than knee** ● Medial talar dome inferior to lateral talar dome ● More than ½ of 5th MT SI on 4th MT (^{2}) ● More than ½ cuboid SI ● Distal fibula less than ¼" distal to distal tibia **Foot higher than knee** ● Medial talar dome superior to lateral talar dome ● Less than ½ of 5th MT SI on 4th MT (^{2}) ● Less than ½ cuboid SI ● Distal fibula more than ¼" distal to distal tibia	MQM pg. 350-356

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LOWER EXTREMITY – TIB/FIB

Part	Projection	CR	Optimal	Error Assessments	Source
Tib/Fib	AP	No angle, vertical beam. Centered for overlap and to include ankle joint and knee joint.	See AP Ankle for distal tib/fib. See AP Knee for proximal tib/fib. Note that the divergent ray will cause both the ankle and knee joints to be demonstrated closed.		MQM pg. 356-360
	Lateral	No angle, vertical beam. Centered for overlap and to include ankle joint and knee joint.	See AP Ankle for distal tib/fib. See AP Knee for proximal tib/fib. Note that the divergent ray will cause both the ankle and knee joints to be demonstrated closed.		MQM pg. 360-363

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LOWER EXTREMITY – KNEE

Part	Projection	CR	Optimal	Error Assessments	Source
KNEE	AP	5° caudal to 5° cephalic, parallel to tibial plateau. Centered at knee joint to include distal ¼ of femur to proximal ¼ of lower leg.	**Rotation** ● ½ of fibular head SI on tibia ● Intercondylar eminence mid femoral notch **CR angle** ● Anterior and posterior aspects of tibial plateau SI ● Knee joint open ● Fibular head ½" distal to tibial plateau	**External Rotation** ● More than ½ of fibular head SI on tibia **Internal Rotation** ● Less than ½ of fibular head SI on tibia **CR angle too cephalad** ● Anterior and posterior aspects of tibial plateau not SI ● Fibular head more than ½" distal to tibial plateau **CR angle too caudal (or not cephalic enough)** ● Anterior and posterior aspects of tibial plateau not SI ● Fibular head less than ½" distal to tibial plateau	MQM pg. 363-372
	External Oblique	5° caudal to 5° cephalic, parallel to tibial plateau. Centered at knee joint to include distal ¼ of femur to proximal ¼ of lower leg.	**Rotation** ● Fibular head fully SI on tibia and aligned to anterior surface of tibia **CR angle** ● Anterior and posterior aspects of tibial plateau SI ● Knee joint open ● Fibular head ½" distal to tibial plateau	**Under rotation** ● Fibular head not fully SI on tibia **Over Rotation** ● Fibular head demonstrated more posteriorly on tibia **CR angle too cephalad** ● Anterior and posterior aspects of tibial plateau not SI ● Fibular head more than ½" distal to tibial plateau **CR angle too caudal (or not cephalic enough)** ● Anterior and posterior aspects of tibial plateau not SI ● Fibular head less than ½" distal to tibial plateau	MQM pg. 373-377

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Part	Projection	CR	Optimal	Error Assessments	Source
KNEE	Internal Oblique	5° caudal to 5° cephalic, parallel to tibial plateau. Centered at knee joint to include distal ¼ of femur to proximal ¼ of lower leg.	**Rotation** ● Fibular head free of SI from tibia **CR angle** ● Anterior and posterior aspects of tibial plateau SI ● Knee joint open ● Fibular head ½" distal to tibial plateau	**Under rotation** ● Fibular head still SI on tibia **Over Rotation** ● Femoral condyles start to SI **CR angle too cephalad** ● Anterior and posterior aspects of tibial plateau not SI ● Fibular head more than ½" distal to tibial plateau **CR angle too caudal (or not cephalic enough)** ● Anterior and posterior aspects of tibial plateau not SI ● Fibular head less than ½" distal to tibial plateau	MQM pg. 373-377
	Lateral	5°-7° cephalic. Centered at knee joint to include distal ¼ of femur to proximal ¼ of lower leg.	**Rotation** ● Femoral condyles SI anteroposteriorly ● ½ of fibular head SI on tibia **CR Angle** ● Femoral condyles SI inferosuperiorly ● Fibular head ½" distal to tibial plateau	**External Rotation** ● Medial femoral condyle anterior to lateral condyle ● Less than ½ fibular head SI on tibia **Internal Rotation** ● Medial femoral condyle posterior to lateral condyle ● More than ½ fibular head SI on tibia **CR angle too cephalic (or leg adduction for x-table lateromedial)** ● Medial femoral condyle superior to lateral condyle ● Fibula more than ½" distal to tibial plateau **CR angle not cephalic enough (or leg abduction for x-table lateromedial)** ● Medial femoral condyle inferior to lateral condyle ● Fibula less than ½" distal to tibial plateau	MQM pg. 378-390

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LOWER EXTREMITY – FEMUR

Part	Projection	CR	Optimal	Error Assessments	Source
FEMUR	AP	No angle, vertical beam. Centered for overlap and to include knee joint and hip joint.	**Rotation for Proximal Femur** ● Greater tuberosity in profile laterally ● Lesser tuberosity SI on femur **Rotation for Distal Femur** ● Femoral condyles in profile ● ½ of fibular SI on tibia ● LT SI on femur	**External Rotation for Proximal Femur** ● GT not in profile laterally ● LT seen medially **External Rotation for Distal Femur** ● More than ½ of fibular SI on tibia **Internal Rotation for Distal Femur** ● Less than ½ of fibular SI on tibia	MQM pg. 412-419
	Lateral	No angle, vertical beam. Centered for overlap and to include knee joint and hip joint.	See Frog-Leg Lateral Hip or X-table Lateral Hip for Proximal Femur. See Lateral Knee for Distal Femur. Please note that Distal Femur does not require a cephalic angle.	See Frog-Leg Lateral Hip or X-table Lateral Hip for Proximal Femur. See Lateral Knee for Distal Femur. Please note that Distal Femur does not require a cephalic angle.	Frog-Leg: MQM pg. 441-445 X-table: MQM pg. 445-450 Lat Knee: MQM pg. 378-390

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PELVIC GIRDLE

Part	Projection	CR	Optimal	Error Assessments	Source
PELVIS /HIP	AP	No angle, vertical beam. Centered midsagittal halfway between ASIS and PS.	**Pelvic Rotation** ● Ala, ischial spines, obturator foramina are symmetrical ● Coccyx aligned with PS **Internal Leg Rotation** ● Lesser tuberosities SI on femora ● Greater tuberosities in profile laterally	**Pelvic rotation towards right** ● Right ala more broad ● Right ischial spine more visible ● Right obturator foramen smaller ● PS to the right of coccyx **Pelvic rotation towards left** ● Left ala more broad ● Left ischial spine more visible ● Left obturator foramen smaller ● PS to the left of coccyx **Insufficient internal femoral rotation** ● Lesser tuberosities still visible ● Greater tuberosities not in profile laterally	MQM pg. 427-432 and 437-441
HIP	Frog Leg Lateral	No angle, vertical beam. Centered at femoral neck to include ASIS to proximal femur.	**Pelvic Rotation** ● Coccyx aligned with PS **Hip flexion at approx. 60° to the table** ● GT SI on femur **Knee abduction at approx. 45° to the table** ● GT halfway between femoral head and LT	**Pelvic rotation towards affected side** ● Ala more broad ● Ischial spine more visible ● Obturator foramen smaller **Pelvic rotation away from affected side** ● Ala more narrow ● Ischial spine more SI on acetabulum ● Obturator foramen more open **Too much hip flexion** ● GT seen medial **Not enough hip flexion** ● GT seen lateral **Too much knee abduction** ● GT seen closer to femoral head than to LT **Not enough knee abduction** ● GT seen closer to LT than to femoral head	MQM pg. 433-436 and 441-445

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Part	Projection	CR	Optimal	Error Assessments	Source
HIP	Cross-table Lateral (Axiolateral)	45^{o} horizontal beam, (perpendicular to the femoral neck) centered at femoral neck to include acetabulum to proximal femur and ischial tuberosity.	**Internal Femoral Rotation** ● GT SI on femur **Pelvic Rotation ([2])** ● Medial and lateral aspects of ischial tuberosity SI **Optimal CR Angle or Stretcher Angle (relative to upright bucky)** ● GT and LT on approximately the same transverse plane **Adequate Flexion of Unaffected Leg** ● ST of unaffected leg not obstructing affected femoral head and neck	**Insufficient internal femoral rotation** ● GT demonstrated posteriorly **Pelvic rotation towards affected side([2])** ● Medial aspect of ischial tuberosity more anterior **Pelvic rotation away from affected side([2])** ● Lateral aspect of ischial tuberosity more anterior **CR angle too large from affected leg or feet too close to bucky** ● LT more distal than GT **CR angle too small from affected leg or feet too far from bucky** ● LT more proximal than GT	MQM pg. 445-450

HEAD – SKULL, SINUSES, FACIAL BONES and MANDIBLE

Projection	Part	CR	Optimal	Error Assessments	Source
AP/PA	Skull	No angle, horizontal beam. Centered at glabella to include vertex to skull base.	**Rotation** ● Distance from lateral orbits to lateral skull margin equal on both sides **Chin Position (or CR angle if used)** ● Petrous ridges SI on supraorbital rims	**Rotation towards the right** ● Distance from orbits to lateral skull margin smaller on the right side than the left side **Rotation towards the left** ● Distance from orbits to lateral skull margin smaller on the left side than the right side **Chin too high *(AP: angle too cephalic; PA: angle too caudal)*** ● Petrous ridges inferior to supraorbital rims **Chin too low *(AP: angle too caudal; PA: angle too cephalic)*** ● Petrous ridges superior to supraorbital rims	MQM pg. 531-539
	Mandible	No angle, horizontal beam. Centered at mandibular angle to include entire mandible.			
15° CALDWELL	Skull	15° cephalic (AP) or caudal (PA), centered at nasion to include vertex to skull base.	**Rotation** ● Distance from lateral orbits to lateral skull margin equal on both sides **Chin Position** ● Petrous ridges demonstrated in lower ⅓ of orbits	**Rotation towards the right** ● Distance from orbits to lateral skull margin smaller on the right side than the left side **Rotation towards the left** ● Distance from orbits to lateral skull margin smaller on the left side than the right side **Chin too high *(AP: angle too cephalic; PA: angle too caudal)*** ● Petrous ridges inferior to lower ⅓ of orbits **Chin too low *(AP: angle too caudal; PA: angle too cephalic)*** ● Petrous ridges superior to lower ⅓ of orbits	MQM pg. 539-543
	Sinuses	No angle, horizontal beam. Centered at nasion to include frontal sinuses to ethmoid sinuses.			
	Facial Bones				

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Projection	Part	CR	Optimal	Error Assessments	Source
WATERS (Parieto-acanthial)	Sinuses	No angle, horizontal beam. Centered at acanthion to include frontal sinuses to sphenoid sinuses.	**Rotation** ● Distance from lateral orbits to lateral skull margin equal on both sides **Chin Position** ● Petrous ridges demonstrated just inferior to maxillary sinuses	**Rotation towards the right** ● Distance from orbits to lateral skull margin smaller on the right side than the left side **Rotation towards the left** ● Distance from orbits to lateral skull margin smaller on the left side than the right side **Chin too high** ● Petrous ridges too inferior to maxillary sinuses ● Molar teeth start to SI on maxillary sinuses **Chin too low** ● Petrous ridges within maxillary sinuses	MQM pg. 553-557
	Facial Bones	No angle, horizontal beam. Centered at acanthion to include frontal sinuses to mandible.			
30° TOWNE	Skull	30° caudad centered 2.5” above glabella to include skull vertex to base.	**Rotation** ● Distance from dorsum sellae to edges of foramen magnum equal on both sides **Chin Position or CR angle** ● Dorsum sellae demonstrated within foramen magnum	**Rotation towards the right** ● Distance from dorsum sellae to foramen magnum smaller on the right side than the left side **Rotation towards the left** ● Distance from dorsum sellae to foramen magnum smaller on the left side than the left side **Chin too high or CR angle not caudal enough** ● Dorsum sellae seen superior to foramen magnum **Chin too low or CR angle too caudal** ● Dens seen SI over dorsum sellae within foramen magnum	MQM pg. 543-547

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Projection	Part	CR	Optimal	Error Assessments	Source
LATERAL	Skull	No angle, horizontal beam. Centered 2" superior to EAM to include skull vertex to base.	**Rotation** ● Sella turcica seen in profile ● Mandibular rami and maxillary sinuses SI anteroposteriorly **Head Vertex Tilt** ● Supraorbital margins SI inferosuperiorly	**Head rotation towards the IR** ● More magnified mandibular ramus demonstrated anterior **Head rotation away from IR** ● More magnified mandibular ramus demonstrated posterior **Vertex tilt towards IR** ● Supraorbital margins not SI inferosuperiorly ● Foramen of C1 closed **Vertex tilt away from IR** ● Supraorbital margins not SI inferosuperiorly ● Foramen of C1 open	MQM pg. 547-550
	Sinuses	No angle, horizontal beam. Centered midway between outer canthus and EAM to include frontal sinuses to maxillary sinuses, and posteriorly to sella turcica.	**Rotation** ● Sella turcica seen in profile ● Greater sphenoid wings and maxillary sinuses SI anteroposteriorly **Head Vertex Tilt** ● Supraorbital margins SI inferosuperiorly	****Assess direction of head rotation by looking at patient**** **Vertex tilt towards IR** ● Supraorbital margins not SI inferosuperiorly ● Foramen of C1 closed **Vertex tilt away from IR** ● Supraorbital margins not SI inferosuperiorly ● Foramen of C1 open	MQM pg. 547-550
	Facial Bones	No angle, horizontal beam. Centered at zygoma, midway between outer canthus and EAM to include frontal sinuses to mandible and posteriorly to sella turcica.			

SPINE – CERVICAL

Part	Projection	CR	Optimal	Error Assessments	Source
CERVICAL SPINE	AP	15^{O} - 20^{O} cephalic. Centered at bottom of Adam's apple (C4) to include C2 to T1.	**Rotation** ● Spinous processes midline ● Clavicles equidistant to vertebral column **CR Angle** ● Each vertebral spinous process seen in the immediately *inferior disc space* ● Disc spaces open **Chin Position** ● Mental protuberance SI on base of skull	**Rotation towards the right** ● Spinous processes seen to the left of midline ● Right clavicle further from spine than left **Rotation towards the left** ● Spinous process seen to the right of midline ● Left clavicle further from spine than right **CR angle too cephalic** ● Spinous process demonstrated in immediately *inferior vertebral body* ● Bifid shape of spinous processes well demonstrated[1] ● Disc spaces closed **CR angle not cephalic enough** ● Spinous process demonstrated in its *own vertebral body* ● Bifid shape of spinous processes not well demonstrated[1] ● Disc spaces closed **Chin too high** ● Mental protuberance superior to base of skull **Chin too low** ● Base of skull superior to mental protuberance	MQM pg. 457-462

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Part	Projection	CR	Optimal	Error Assessments	Source
CERVICAL SPINE	Dens	No angle, horizontal or vertical beam. Centered at dens to include C1 and C2 .	**Rotation** ● Spinous process of C2 midline **Chin Position** ● Upper incisors SI on base of skull	**Rotation towards the right** ● C2 spinous process seen to the left of midline **Rotation towards the left** ● C2 spinous process seen to the right of midline **Chin too high** ● Upper incisors superior to base of skull **Chin too low** ● Upper incisors inferior to base of skull	MQM pg. 462-467
	Oblique	15^{O} - 20^{O} cephalic (for AP) 15^{O} - 20^{O} caudad (for PA) Centered at bottom of Adam's apple (C4) to include C1 to T1.	**Rotation** ● Pedicle of interest in profile ● Other pedicle aligned to anterior aspect of vertebral body ● Intervertebral foramina open **LPO/RAO demonstrates right pedicle in profile and right intervertebral foramina** ** RPO/LAO demonstrates left pedicle in profile and left intervertebral foramina** **Head Tilt (Interpupillary Line Positioning)** ● Mandibular rami separated inferosuperiorly by approx. ½"	**Over Rotation** ● Pedicle of interest not in profile ● Other pedicle more posterior on vertebral body ● Intervertebral foramina narrowed ● Image appears more like a lateral projection **Under Rotation** ● Pedicle of interest not in profile ● Other pedicle more anterior on vertebral body ● Intervertebral foramina narrowed ● Image appears more like an AP projection **Head Tilt Towards the IR** ● Mandibular rami separated inferosuperiorly by more than ½" **Head Tilt Away from IR** ● Mandibular rami separated inferosuperiorly by less than ½"	MQM pg. 473-478

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Part	Projection	CR	Optimal	Error Assessments	Source
CERVICAL SPINE	Lateral	No angle, horizontal or vertical beam. Centered at bottom of Adam's apple (C4) to include C1 to T1.	**Rotation** ● Articular pillars, zygapophyseal joints and posterior aspects of each vertebral body SI anteroposteriorly **Head Tilt** ● Articular pillars and zygapophyseal joints SI inferosuperiorly	**Rotation** ● Identifying more magnified aspects will provide moderately reliable clues to which way the patient is rotated **Head tilt towards the IR** ● Articular pillars and zygapophyseal joints separated inferosuperiorly ● Intervertebral foramen of C2 open **Head tilt away from the IR** ● Articular pillars and zygapophyseal joints separated inferosuperiorly ● Intervertebral foramen of C2 closed	MQM pg. 467-472

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SPINE – THORACIC and LUMBAR

Part	Projection	CR	Optimal	Error Assessments	Source
THORACIC SPINE	AP	No angle, vertical beam. Centered halfway between jugular notch and xiphoid to include C7 to L1.	**Rotation** ● Spinous processes midline ● Clavicles equidistant to vertebral column	**Rotation towards the right** ● Spinous processes seen to the left of midline ● Right clavicle further from spine than left **Rotation towards the left** ● Spinous process seen to the right of midline ● Left clavicle further from spine than right	MQM pg. 481-484
	Lateral		**Rotation** ● Posterior aspects of each vertebral body SI anteroposteriorly ● Left and right posterior ribs SI within ½" of each other	**Anterior rotation (slightly LAO)** ● More magnified ribs demonstrated anterior to other ribs **Posterior rotation (slightly LPO)** ● More magnified ribs demonstrated posterior to other ribs	MQM pg. 418-422
LUMBAR SPINE	AP	No angle, vertical beam. Centered at LCM (L3) to include T12 to SI joints.	**Rotation** ● Spinous processes midline	**Rotation towards the right** ● Spinous processes seen to the left of midline **Rotation towards the left** ● Spinous process seen to the right of midline	MQM pg. 491-495
	Lateral		**Rotation** ● Posterior aspects of each vertebral body SI anteroposteriorly ● Left and right posterior ribs SI within ½" of each other	**Anterior rotation (slightly LAO)** ● More magnified ribs demonstrated anterior to other ribs **Posterior rotation (slightly LPO)** ● More magnified ribs demonstrated posterior to other ribs	MQM pg. 498-503

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THORAX – CHEST

Part	Projection	CR	Optimal	Error Assessments	Source
CHEST	AP/PA	*PA:* No angle, horizontal beam. *AP:* Caudal angle to match angle of chest. Centered at inferior scapular angle (T7) to include apices to costophrenic angles.	**Rotation** ● Spinous processes midline ● Clavicles equidistant to vertebral column **Coronal Plane Tilt (or CR angle for AP Projections)** ● Medial clavicular ends at the level of T3 (or SI on ribs 3 or 4 ([1])) **Shoulder Depression** ● Medial and lateral ends of clavicles on almost the same horizontal plane **Shoulder Protraction (rolled anteriorly)** ● Scapulae demonstrated outside of lung fields **Inspiration** ● 10 posterior ribs demonstrated within lung fields	**Rotation towards the right** ● Spinous processes seen to the left of midline ● Right clavicle further from spine than left **Rotation towards the left** ● Spinous process seen to the right of midline ● Left clavicle further from spine than right **Anterior coronal tilt or too much caudal angle** ● Medial clavicular ends inferior to T3 (or inferior to rib 4 ([1])) **Posterior coronal tilt or not enough caudal angle** ● Medial clavicular ends superior to T3 (or superior to rib 3 ([1])) **Shoulder elevation** ● Clavicles not SI on apices	MQM pg. 89-97
	Lateral	No angle, horizontal beam. Centered at T8 to include apices to costophrenic angles and posterior ribs.	**Rotation** ● Posterior ribs SI or within ½" of each other **Inspiration** ● Diaphragms inferior to T11 **Arms Raised** ● No humeral soft tissue SI on lung fields	**Posterior rotation (slightly LPO)** ● More magnified right sided ribs posterior to left ribs **Anterior rotation (slightly LAO)** ● More magnified right sided ribs anterior to left ribs **Inadequate inspiration** ● Exaggerated bow to hemidiaphragms ● Diaphragms above T11	MQM pg. 91-98

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THORAX – RIBS

Part	Projection	CR	Optimal	Error Assessments	Source
RIBS	AP/PA	No angle, horizontal or vertical beam. *Upper ribs*: Centered to include 1" above apices and below.(1) *Lower ribs*: Centered to include just above iliac crests and up.	**Rotation** ● Spinous processes midline ● Clavicles equidistant to spine **Inspiration for Upper Ribs** ● At least 8 ribs above diaphragms **Expiration for Lower Ribs** ● At least ribs 8-12 below diaphragms	**Rotation towards the right** ● Spinous processes seen to the left of midline ● Right clavicle further from spine than left **Rotation towards the left** ● Spinous process seen to the right of midline ● Left clavicle further from spine than right	MQM pg. 522-527
	Oblique		**Rotation** ● Axillary ribs demonstrated free of SI ● Inferior sternum body midway between spine and lateral margins of ribs **Inspiration for Upper Ribs** ● At least 8 axillary ribs above diaphragms **Expiration for Lower Ribs** ● At least axillary ribs 9-12 below diaphragms	**Under rotation** ● Inferior sternum body closer to spine than to lateral margins of ribs **Over rotation** ● Inferior sternum body closer to lateral margins of ribs than to spine	MQM pg. 527-530

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ABDOMEN

Part	Projection	CR	Optimal	Error Assessments	Source
ABDOMEN	AP Supine	No angle, horizontal beam. Centered at iliac crests to include pubic symphysis and up.	**Rotation** ● Spinous processes midline ● Pelvic structures symmetrical (ala, obturator foramina, ischial spines, coccyx midline and aligned to PS) **Image Quality** ● Contrast and brightness optimal to demonstrate psoas muscle, kidneys, ribs and transverse processes of l-spine are visualized	**Rotation towards the right** ● Spinous processes seen to the left of midline ● Right ala broader ● Right obturator foramen more narrow ● Right ischial spine more visible ● PS to the right of coccyx **Rotation towards the left** ● Spinous processes seen to the right of midline ● Left ala broader ● Left obturator foramen more narrow ● Left ischial spine more visible ● PS to the left of coccyx	MQM pg. 138-149
	AP/PA Upright	No angle, horizontal beam. Centered at LCM to include diaphragms and down.			
	AP/PA Left Lateral Decubitus				MQM pg. 138-141 and 149-151

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*Reviewers may be cited as numerical superscripts throughout manual.

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