Screen-Film Radiography

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4th- year Medical

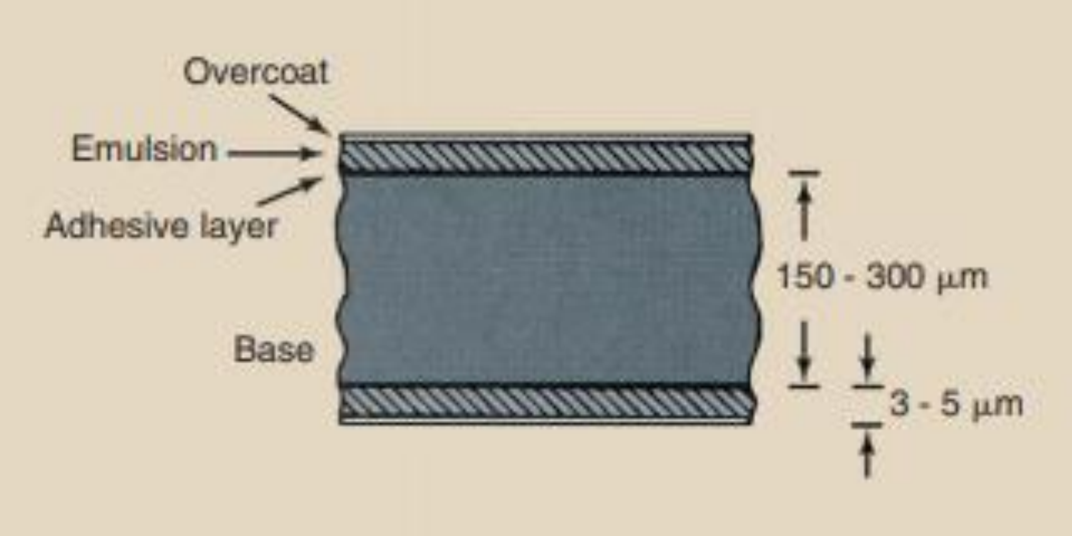
Image Forming

The primary purpose of radiographic imaging is to transfer information from an x-ray beam to the eye– brain complex of the radiologist. The x-ray beam that emerges from the x-ray tube is nearly uniformly distributed in space. After interaction with the patient, the beam of image-forming x-rays is not uniformly distributed in space but varies in intensity according to the characteristics of the tissue through which it has passed.

The exit x-ray beam refers to the x-rays that remain as the useful beam exits the patient. It consists of x-rays scattered away from the image receptor and image forming x-rays. The diagnostically useful information in this exit x-ray beam must be transferred to a form that is intelligible to the radiologist. X-ray film is one such medium. Other media include the fluoroscopic image intensifier, the television or flat panel monitor, the laser imaging system, and solid-state detectors. The medium that converts the x-ray beam into a visible image is called the image receptor (IR). The classical IR is photographic film, although solid state digital IRs are replacing film.

RADIOGRAPHIC FILM

The manufacture of radiographic film is a precise procedure that requires tight quality control. Manufacturing facilities are extremely clean because the slightest bit of contaminant in the film limits the film’s ability to reproduce information from the x-ray beam. Radiographic film has two parts: **the base and the emulsion**.



In most x-ray film, the emulsion is coated on both sides; therefore, it is called double emulsion film. Between the emulsion and the base is a thin coating of material called the adhesive layer, which ensures uniform adhesion of the emulsion to the base. This adhesive layer allows the emulsion and the base to maintain proper contact and integrity during use and processing. The emulsion is enclosed by a protective covering of gelatin called the overcoat. This overcoat protects the emulsion from scratches, pressure, and contamination during handling, processing, and storage. The thickness of radiographic film is **approximately 150 to 300 µm.**

Base

The base is the foundation of radiographic film. Its primary purpose is to provide a rigid structure onto which the emulsion can be coated. The base is flexible and fracture resistant to allow easy handling but is rigid enough to be snapped into a view box. Conventional photographic film has a much thinner base than radiographic film and therefore is not as rigid.

The base of radiographic film maintains its size and shape during use and processing so that it does not contribute to image distortion. This property of the base is known as **dimensional stability**. The base is of uniform lucency and is nearly transparent to light. During manufacturing, however, dye is added to the base of most radiographic film to slightly tint the film blue. Compared with untinted film, this coloring reduces eyestrain and fatigue, enhancing radiologists' diagnostic efficiency and accuracy.

In the early 1960s, a **polyester** base was introduced. Polyester has taken the place of **cellulose triacetate** as the film base of choice. Polyester is more resistant to warping from age and is stronger than cellulose triacetate, permitting easier transport through automatic processors. Its dimensional stability is superior. Polyester bases are thinner than triacetate bases (≈175 μm) but are just as strong.

Emulsion

The emulsion is the heart of the radiographic film. It is the material with which x-rays or light photons from radiographic intensifying screens interact. The emulsion consists of a homogeneous mixture of gelatin and silver halide crystals. It is coated evenly with a layer that is 3 to 5 μm thick. The gelatin is similar to that used in salads and desserts but is of much higher quality. It is clear, so it transmits light, and it is sufficiently porous for processing chemicals to penetrate to the crystals of silver halide. Its principal function **is to provide mechanical support for silver halide crystals by holding them uniformly dispersed in place.** The silver halide crystal is the active ingredient of the radiographic emulsion.

In the typical emulsion, 98% of the silver halide is silver bromide; the remainder is usually silver iodide. These atoms have relatively high atomic numbers ($Z_{Br} = 35$; $Z_{Ag} = 47$; $Z_I = 53$) compared with the gelatin and the base (for both, $Z \approx 7$). The interaction of x-ray and light photons with these high-Z atoms ultimately results in the formation of a latent image on the radiograph. The crystals are made by dissolving metallic silver (Ag) in nitric acid (HNO_3) to form silver nitrate ($AgNO_3$). Light-sensitive silver bromide (AgBr) crystals are formed by mixing silver nitrate with potassium bromide (KBr) in the following reaction:

Silver Halide Crystal Formation: $AgNO_3 + KBr \rightarrow AgBr \downarrow + KNO_3$

The arrow ↓ indicates that the silver bromide is precipitated while the potassium nitrate, which is soluble, is washed away.

TYPES OF FILM

Medical imaging is becoming extremely technical and sophisticated, and this is reflected in the number and variety of films that are now available. Each major film manufacturer produces many different films for medical imaging. When combined with the various film formats offered, more than 500 selections are possible (Table 1). In addition to screen-film, direct-exposure film, sometimes called non-screen film and special application film (such as that used in mammography, video recording, duplication, subtraction, cineradiography, and dental radiology), are available. Each has particular characteristics that become more familiar to radiologic technologists with use.

Table. 1 **Types of Film Used in Medical Imaging**

Type	Emulsions	Characteristics	Applications
Intensifying screen	Two	Blue or green sensitive	General radiography
Laser printing	Single with antihalation backing	Matches laser used (≈630 nm)	Laser printers attached to CT, MRI, ultrasonography, and so on
Copy or duplicating	Single with antihalation backing	Pre-exposed	Duplicating radiographs
Dental	Two packed in sealed envelope	Has lead foil to reduce back scatter	Dentistry
Radiation monitoring	Two packed in sealed envelope	One emulsion can be sloughed off to increase OD scale	Radiation monitoring
Dry transfer	One	Thermally sensitive	"Dry" printers

Screen-Film

Screen film is the type of film that is used with radiographic intensifying screens. Several characteristics must be considered when one is selecting screen-film: **contrast, speed, spectral matching, anti-crossover or antihalation dyes, and requirement for a safelight**.

Contrast.

Most manufacturers offer screen film with multiple contrast levels. The contrast of an IR is inversely proportional to its exposure latitude, that is, the range of exposure techniques that produce an acceptable image. Usually, the manufacturer identifies the contrast of these films as medium, high, or higher. The difference depends on the size and distribution of the silver halide crystals. A high-contrast emulsion contains smaller silver halide grains with a relatively uniform grain size. Low-contrast films, on the other hand, contain larger grains that have a wider range of sizes.

Speed.

Screen-film IRs are available with different speeds. Speed is the sensitivity of the screen-film combination to x-rays and light. Usually, a manufacturer offers several different IRs of different speeds that result from different film emulsions and different intensifying screen phosphors.

For direct-exposure film, speed is principally a function of the concentration and the total number of silver halide crystals. For screen film, **silver halide grain size, shape, and concentration** are the principal determinants of film speed.

Compared with earlier technology, current emulsions contain less silver yet produce the same optical density (OD) per unit exposure. This more efficient use of silver in the emulsion is called the covering power of the emulsion.

Crossover.

Until recently, silver halide crystals were usually flat and three dimensional (Figure.1, A). Most emulsions now (Figure.1, B) contain tabular grains, which are flat silver halide crystals, and provide a large surface area–to-volume ratio. The result is improved covering power and significantly lower crossover. When light is emitted by a radiographic intensifying screen, it not only exposes the adjacent emulsion, it can also expose the emulsion on the other side of the base. When light crosses over the base, it causes increased blurring of the image (Figure.2).

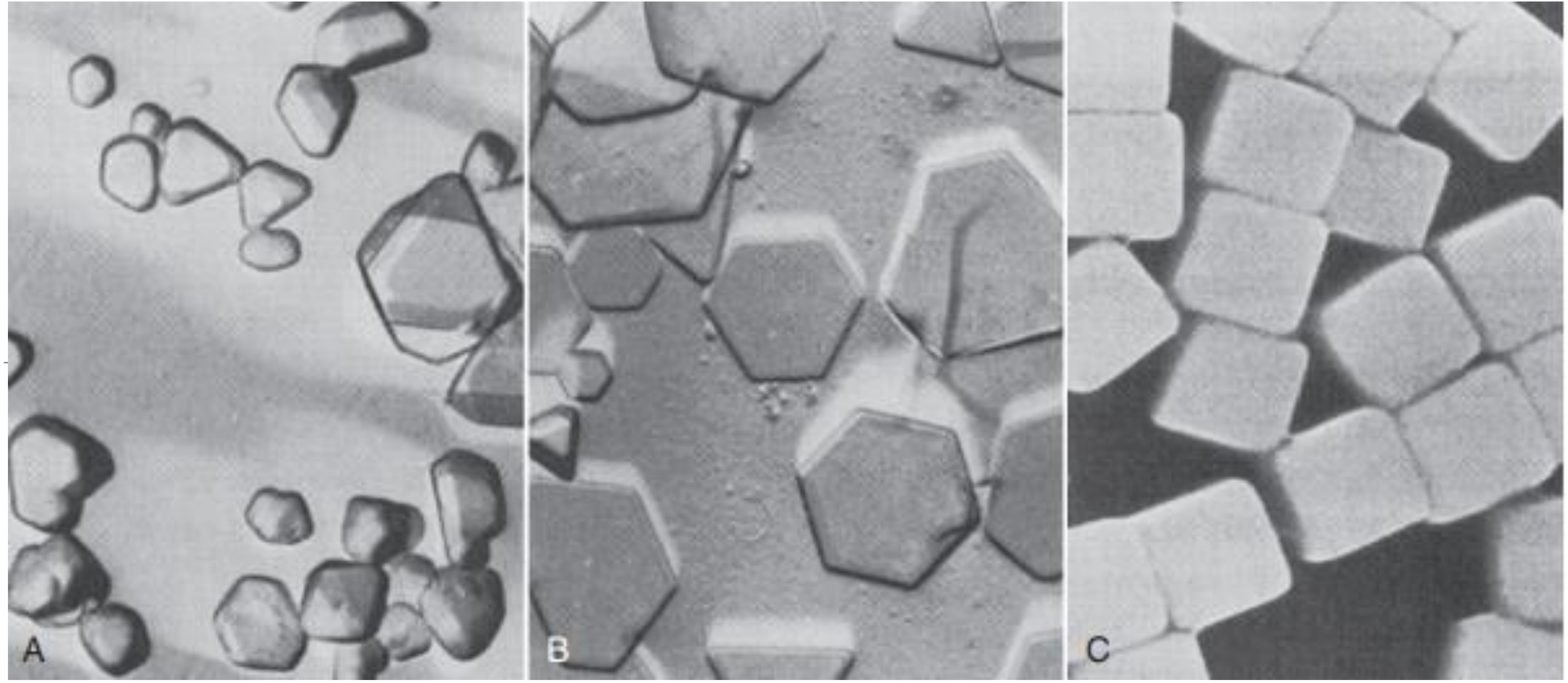
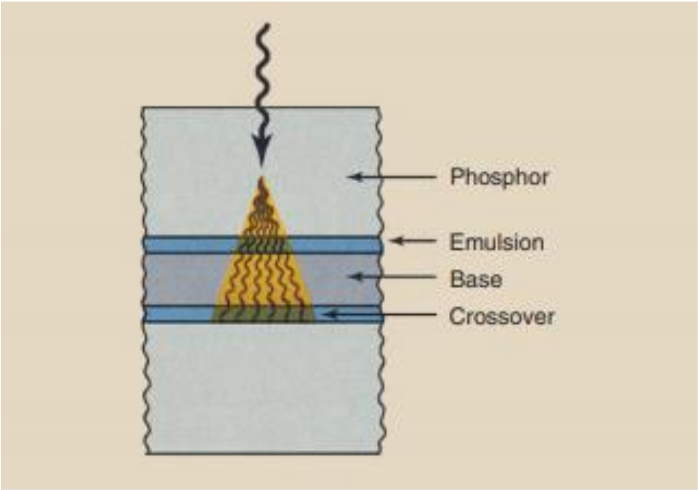


Figure.1 A, Conventional silver halide crystals are irregular in size. B, New technology produces flat, tablet-like grains. C, Cubic grains.

Figure. 2 Crossover occurs when screen light crosses the base to expose the opposite emulsion.



How we can reduce Crossover

Tabular grain emulsions reduce crossover because the covering power is increased, which relates not only to light absorption from the screen (which is increased) but also to light transmitted through the emulsion to cause crossover (which is reduced).

The addition of a light-absorbing dye in a crossover control layer reduces crossover to near zero. The crossover control layer has three critical characteristics: (1) It absorbs most of the crossover light, (2) it does not diffuse into the emulsion but remains as a separate layer, and (3) it is completely removed during processing.

RADIOGRAPHIC IMAGE

Quality is the exactness of representation of the patient's anatomy on a radiographic image. High-quality images are required so that radiologists can make accurate diagnoses. To produce high-quality images, radiographers apply knowledge of the three major interrelated categories of radiographic quality: **film factors, geometric factors, and subject factors**. Each of these factors influences the quality of a radiographic image, and each is under the control of radiologic technologists. The most important characteristics of radiographic image quality are **spatial resolution, contrast resolution, noise, and artifacts.**

Spatial resolution improves as screen blur decreases, motion blur decreases, and geometric blur decreases.

Contrast resolution is the ability to distinguish anatomical structures of similar subject contrast such as liver–spleen and gray matter–white matter. The actual size of objects that can be imaged is always smaller under conditions of high subject contrast than under conditions of low subject contrast.

Noise

Noise is a term that is borrowed from electrical engineering. The flutter, hum, and whistle heard from an audio system constitute audio noise that is inherent in the design of the system.

Radiographic noise is the random fluctuation in the OD of the image.

Radiographic Quality Rules

1. Fast image receptors have high noise and low spatial resolution and low contrast resolution.
2. High spatial resolution and high contrast resolution require low noise and slow image receptors.
3. Low noise accompanies slow image receptors with high spatial resolution and high contrast resolution.

In general, the quality of a radiograph is directly related to an understanding of the basic principles of x-ray physics and the factors that affect radiographic quality. Figure.3 is an organizational chart of the principal factors that affect screen-film radiographic quality, most of which are under the control of radiologic technologists.

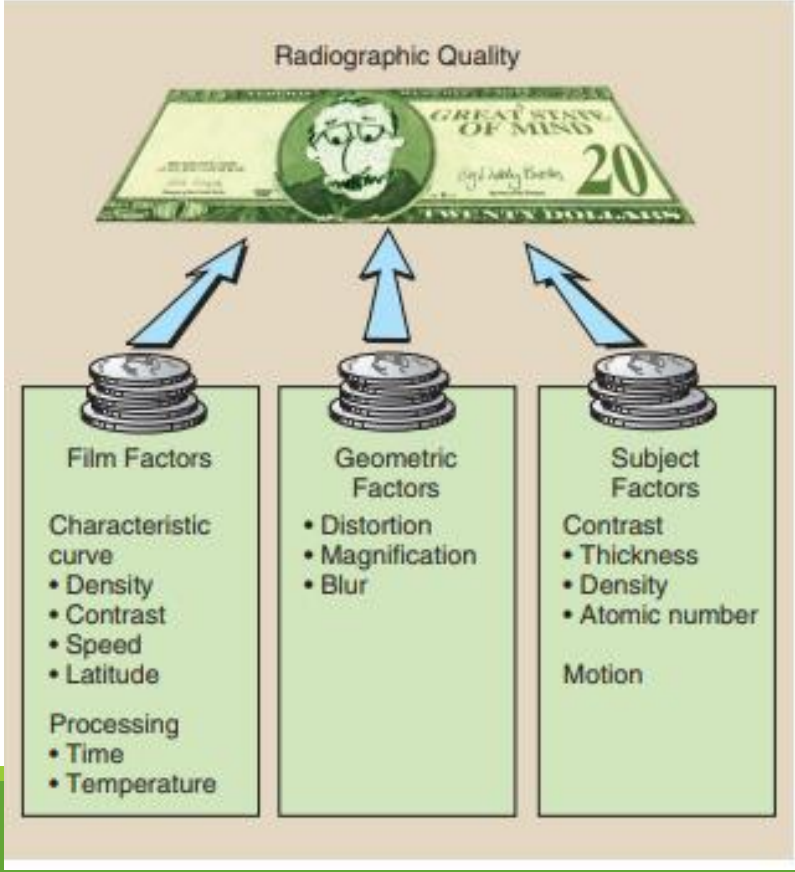
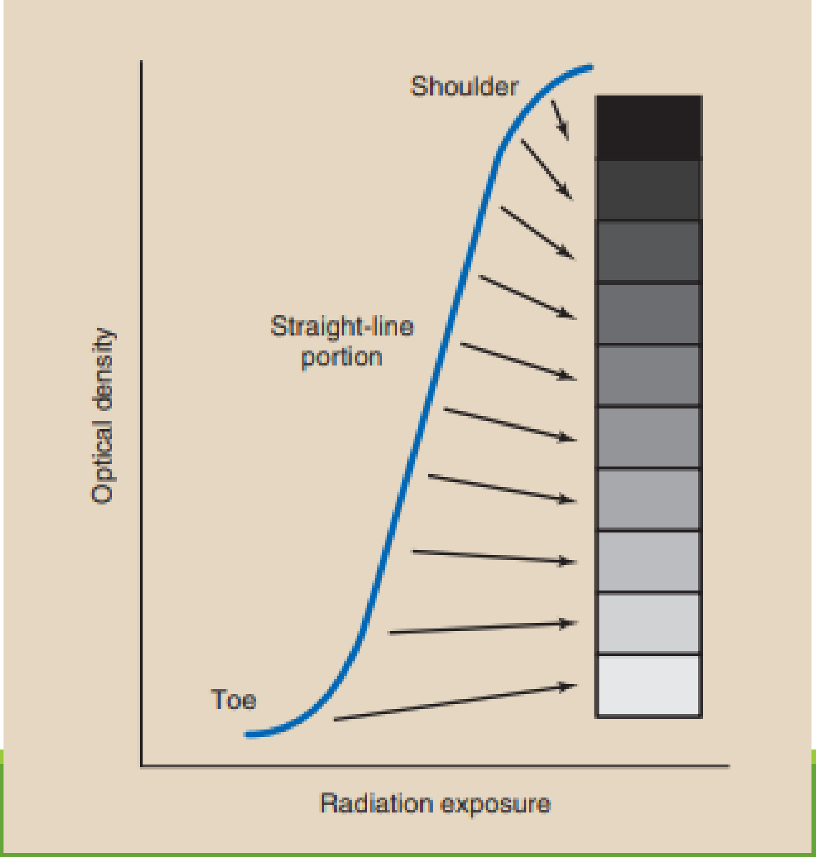


Figure.3 Organization chart of principal factors that may affect radiographic quality.

Characteristic Curve

A typical characteristic curve is shown in Figure 4. At low and high radiation exposure levels, large variations in exposure result in only a small change in OD. These portions of the characteristic curve are called the toe and the shoulder, respectively. At intermediate radiation exposure levels, small changes in exposure result in large changes in OD.

Figure. 4 The characteristic curve of a radiographic screen-film image receptor is the graphic relationship between optical density (OD) and radiation exposure.



Optical Density

Optical Density It is not enough to say that OD is the degree of blackening of a radiograph or that a clear area of the radiograph represents low OD and a black area represents high OD. OD has a precise numeric value that can be calculated if the level of light incident on a processed film (Io) and the level of light transmitted through that film (It) are measured. The OD is defined as follows:

Optical Density

$$OD = \log_{10} \frac{I_o}{I_t}$$

Q. The lung field of a chest radiograph transmits only 0.15% of incident light as determined with a densitometer. What is the OD?

Solu.

$$OD = \log_{10}\frac{1}{0.0015}$$

$$= \log_{10} 666.7$$

$$= 2.8$$

Table. 1

Relationship of the Optical Density of Radiographic Film to Light Transmission Through the Film

Percent of Light Transmitted ($I_t/I_o \times 100$)	Fraction of Light Transmitted (I_t/I_o)	Optical Density ($\log I_o/I_t$)
100	1	0
50	1/2	0.3
32	8/25	0.5
25	1/4	0.6
12.5	1/8	0.9
10	1/10	1
5	1/20	1.3
3.2	4/25	1.5
2.5	1/30	1.6
1.25	1/80	1.9
1	1/100	2
0.5	1/200	2.3
0.32	2/625	2.5
0.125	1/800	2.9
0.1	1/1000	3
0.05	1/2000	3.3
0.032	1/3125	3.5
0.01	1/10,000	4