MAMMOGRAPHY - HIGH LEVEL TROUBLESHOOTING

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Objectives:

- Review MQSA and ACR annual QC tests as opportunities for troubleshooting before a significant image quality problem develops.
- Review MQSA equipment evaluations, and the role they play in preventing the need for troubleshooting at a later date.
- Present a logical decision tree approach to troubleshooting specific image quality problems.

The Medical Physicist CAN & SHOULD be an important resource for improving image quality of:

- **Phantom images**

&

- **Clinical images**

Medical Physicist's Services: Compliance or Quality?

- **Growing tendency toward compliance**
  - easier and quicker to meet minimum standards than to improve on them
  - "the MQSA inspector accepts it"
- Both ACR and MQSA encourage the physicist to go beyond compliance checks, and to make recommendations for quality improvement.

Medical Physicist's Services: Compliance or Quality?

- **During annual testing, make suggestions that may lead to improved image quality.**
  - this may prevent more intensive troubleshooting in the future
- ***Example:***
  - ***You see the maximum compression force is set to 30#. Although compliant, you should advise increasing the max to 45#.***

Physicist Level Performance Evaluations & Troubleshooting:

- **ANNUAL quality control compliance testing**
  - MQSA required testing
  - ACR recommended testing
- **Equipment evaluations**
  - New, repaired, relocated equipment
  - MQSA required

Physicist Level Performance Evaluations & Troubleshooting:

- **Troubleshooting (specific problems)**
  - Improving contrast, detail, noise, artifacts, etc
  - Goes beyond performance testing of x-ray units
    - *screen-film appropriateness*
    - *film processing evaluation*
    - *technique factors*
    - *proper use of AEC*
    - *viewing conditions*

Medical Physicist's Services in Mammography:

- **ANNUAL quality control compliance testing**
- **Equipment evaluations**
- Troubleshooting

MQSA Required Annual Physicist QC Survey:

- **The 12 equipment tests in Table 1**
  - testing methods not generally specified
  - see Guidance (www.fda.gov/cdrh/mammography)
- **Evaluation of technologist QC testing**
- **A written summary report**
  - format of report not specified
  - to include recommendations physicist feels may improve the quality of mammography.

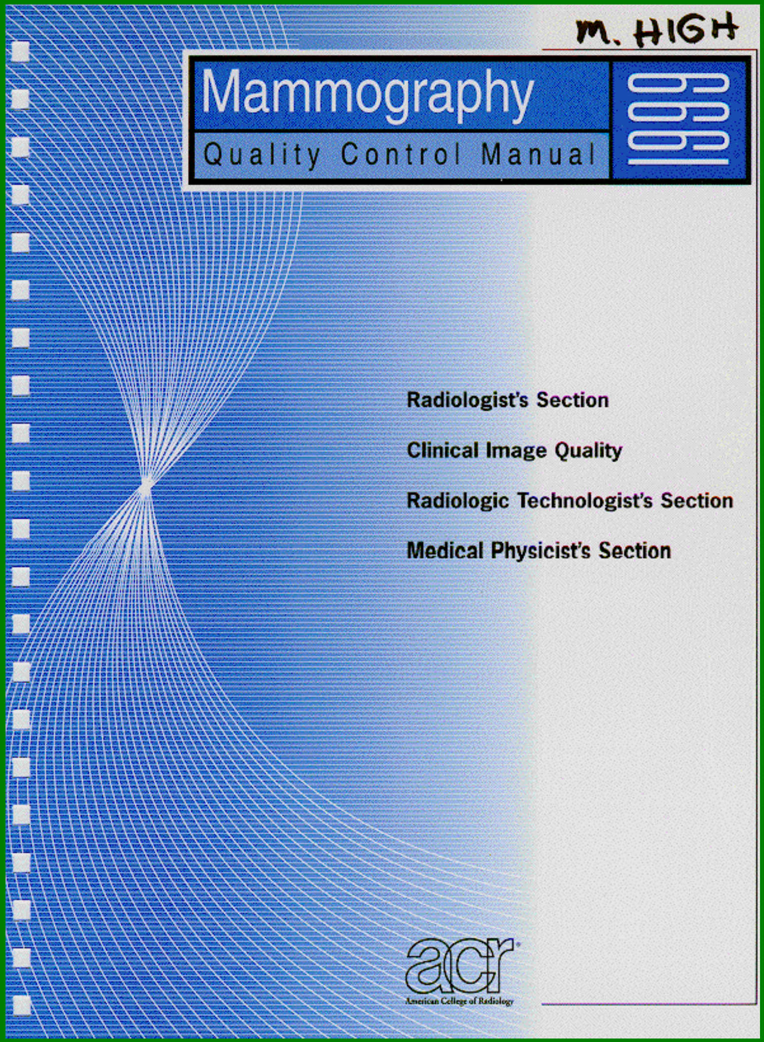
ACR Recommended Annual Physicist QC Tests:

- **The 11 equipment tests in Table 2**
  - testing methods detailed in 1999 ACR Mammography Quality Control Manual
  - tests, action limits, scope of testing are very similar to MQSA, but there are several differences which Medical Physicist must consider, and use profesional judgement to develop a comprehensive performance evaluation.

ACR Recommended Annual Physicist QC Tests:

- **Evaluation of technologist QC testing**
- **A written report including a summary**
  - model report formats are in the ACR manual
  - to include recommendations physicist feels may improve the quality of mammography.

Resources:


M. HIGH
Mammography
Quality Control Manual
Radiologist's Section
Clinical Image Quality
Radiologic Technologist's Section
Medical Physicist's Section
acr
American College of Radiology

Medical Physicist’s Professional Judgment: Tailoring the Tests

- **Guidance documents can never set the scope of testing and limits for all mammography units because:**
  - many different existing designs
  - new designs with new features
  - State Department of Health requirements
- **Professional judgment & knowledge of unit must be used to tailor the tests to the unit**

Multiple Selectable mA Stations:

- **All tests affected by mA should be performed at each clinically used mA station**
  - kVp
  - radiation output rate
  - system resolution
  - small focus is always a different mA station

Multiple Filters (Mo, Rh, Al):

- **All tests affected by filtration should be performed for each clinically used filter**
  - HVL
  - average glandular dose
  - phantom image quality
  - AEC performance
  - artifact evaluation

Multiple Targets (Mo, Rh, W):

- **All tests affected by anode selection should be performed for each clinically used target**
  - HVL
  - average glandular dose
  - phantom image quality
  - AEC performance
  - artifact evaluation

Multiple Auto-kV, Auto-filter Algorithms:

- Selectable maximum exposure time (0.8, 1.6s)
- Selectable dose (STD, CNT, DOSE)
  - HVL
  - average glandular dose
  - phantom image quality
  - AEC performance
- **Test pulses may affect dosemeters**

Multiple AEC Sensors:

- **Some units use separate sensors for small and large Bucky's**
  - Must test thickness/kVp tracking for each

Multiple AEC Sensors:

- **Some units use a matrix of fixed detectors which can be used to find the densest portion of the breast**
  - Must test each detector independently in some way

Multiple Film-Screen Combos:

- **Some facilities use a faster speed screen for mag and/or large Bucky**
  - uniformity of screen speed
  - average glandular dose
  - phantom image quality
  - AEC performance
  - system resolution

Medical Physicist's Professional Judgment: Tailoring the Limits

- **Action limits can often be tightened**
  - kVp accuracy & reproducibility
  - AEC performance can be made better than +/- 0.15 OD for 2 - 8 cm on some units
- **Action limits can be tailored at acceptance testing.**

The Annual Medical Physicist's Survey Report: Requirements

- Communication of results with recommendations is just as important as performing the tests.
- Needed on-site for annual MQSA inspections
- Needed to be submitted with applications for accreditation.

The Medical Physicist's Report: Useful for -

- **Information resource for technologist**
  - Image quality and dose of Rh filter, AEC mode
- **Information resource for service engineer.**
  - Details of calibration deficiencies
- **Information resource for troubleshooting**
  - Performance baseline to which future measurements can be compared

The Medical Physicist's Report: Useful only if -

- **There is sufficient information in report.**
  - **Adequate description of test conditions**
    - kVp, mA, filter, target
    - SID, magnification, receptor size
    - phantom type and thickness
    - AEC settings, compression force
    - screen, film, processing conditions
  - **Test results for complete range of machine settings and modes of operation clinically used**

The Medical Physicist's Report: Useful only if -

- **Contains detailed recommendations for corrective action.**
- **And contains:**

  " …recommendations that will improve image quality, including [those] concerning image receptors, technique factors, processing, viewing conditions and technologist QC." (ACR QC Manual)

Medical Physicist's Services in Mammography:

- ANNUAL quality control compliance testing
- **Equipment evaluations**
- Troubleshooting

Equipment Evaluations: Requirements

- **Before use on patients, a qualified medical physicist must perform an MQSA "equipment evaluation" on :**
  - newly installed mammography equipment (x-ray unit or processor)
  - disassembled and reassembled equipment
  - equipment which has had a ***major*** component changed or repaired.

Equipment Evaluations: New Equipment Acceptance Test

- **ACR Mammography QC Manual:**

  "It is assumed that mammography equipment will have been subjected to more extensive acceptance testing or a thorough performance evaluation prior to initiation of [annual] QC testing."

Equipment Evaluations: New Equipment Acceptance Test

- **MQSA Compliance Guidance**

  "The equipment evaluation is more extensive than the survey. It may be regarded as an acceptance test for equipment and an annual survey alone is not sufficient to meet this requirement."

Equipment Evaluations: Disassembled, Reassembled

- **Relocated, disassembled and reassembled equipment is to be evaluated as newly installed.**
- **A complete acceptance test needed**

Equipment Evaluations: “Major” Repairs

- **New x-ray tube**
- **AEC component replacement**
- **Collimator replacement**
- **Beam filter replacement**
- **Processor reassembly**
- **Generator replacement or re-calibration are considered major repairs.**

Equipment Evaluations: Scope for “Major” Repairs

- **Tests would include all those affected by the component repaired or replaced.**

Equipment Evaluations: Example - New AEC sensor

- **AEC testing**
- **Dose determination**
- **Phantom tests**

Equipment Evaluations: Rebuilt/Replaced Processor

- Sensitometric testing
- Phantom tests
- Artifact evaluation
- Dose determination
- AEC testing
- Verification of proper processing solutions

Equipment Repairs: Physicist Involvement

- **Medical physicist evaluates in person**
- **Medical physicist provides oversight**
- **Medical physicist involvement optional**

- **Should be discussion between facility and medical physicist**

The Mammography Quality Standards Act Final Regulations Document #4

May 23, 2001

www.fda.gov/cdrh/mammography

From CDRH Guidance Document #4

Table: Medical Physicist Involvement in Equipment Adjustments, Changes, or Repairs

For any adjustment, change, or repair not listed in the table below, or if the facility is unsure as to the full extent of the adjustment, change, or repair, the facility should consult their medical physicist to determine the proper extent of his or her involvement in evaluating the item.

Item	Major Repair	Medical Physicist Involvement
Automatic Exposure Control		
AEC Replacement	Y	MP conducts evaluation in person
Thickness compensation internal* adjustment	Y	MP conducts evaluation in person
AEC sensor replacement	Y	MP conducts evaluation in person
AEC circuit board replacement	Y	MP conducts evaluation in person
Density control - internal* adjustment	N	MP oversight
Bucky (New to Facility) Replacement		
AEC also replaced	Y	MP conducts evaluation in person
AEC not replaced	N	MP oversight

Medical Physicist’s Services in Mammography:

- ANNUAL quality control compliance testing
- Equipment evaluations
- **Troubleshooting**

Manufacturer's Troubleshooting Resources:

- Film processor service company
- Film manufacturer representative
- Mammography unit service engineer
- Mammography unit applications person

- Should be advised where appropriate

Manufacturer's Troubleshooting Resources may not resolve issue -

- Poorly trained service person
- Narrow focus and expertise of individual
- Management decisions resulting in poorly compatible system components
  - film/screen/chemistry/processor
- Physicist can analyze entire imaging system to determine where improvement can be made.

Troubleshooting by the Medical Physicist

- Involvement of medical physicist in solving specific problems concerning image quality
- Will evaluate entire imaging chain
  - Film processing
  - Film-Screen combination
  - X-ray unit
  - Technologist technique

Triggering Events for Physicist's Troubleshooting: #1

- **Failure of Technologist's QC test**
  - **processor sensitometry**
  - **phantom image quality**

- **Physicist must be knowledgeable in performing technologist's tests and in all variables which affect test results.**

Triggering Events for Physicist's Troubleshooting: #2

- **Patient's current mammograms perceived to be not as good as previous images.**
- **Physicist must**
  - separate reality from impression
  - establish which image quality parameter degraded
  - establish possible cause of degraded parameter
  - make recommendations for improvement

Triggering Events for Physicist's Troubleshooting: #3

- Facility fails its application for accreditation because of image quality

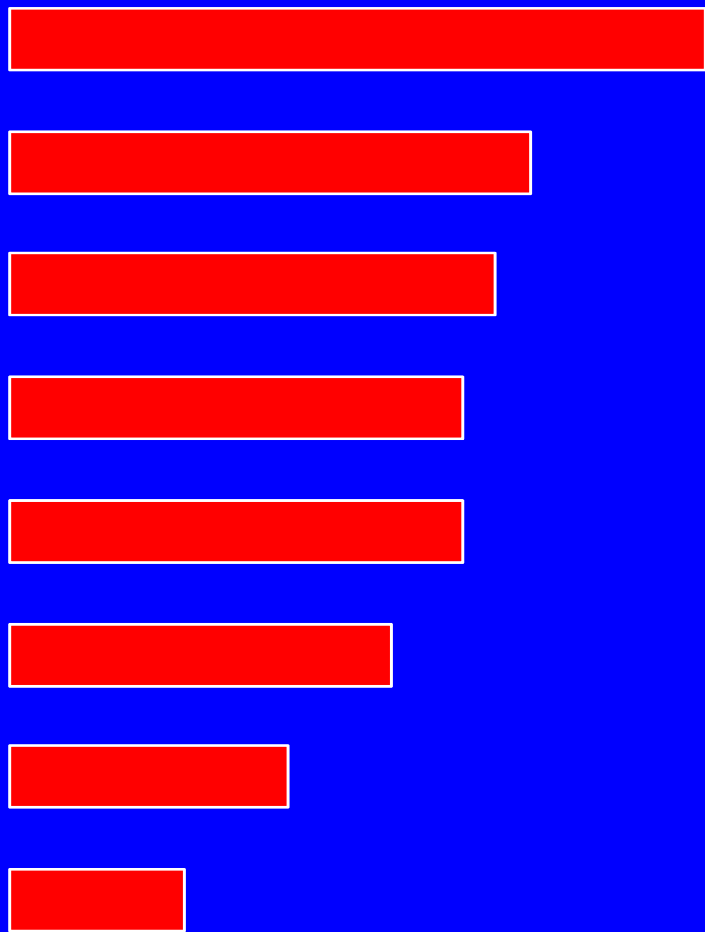
- This risk can be reduced if physicist reviews all images before submission.
- Of course physicist must be familiar with the image quality criteria used by the ACR for both phantom and clinical images

ACR Image Quality Criteria for Clinical Images:

- ACR Mammography QC Manual
- Accreditation Application Package
- Accreditation Results Report returned to facility
- Literature (Bassett et al. 2000)

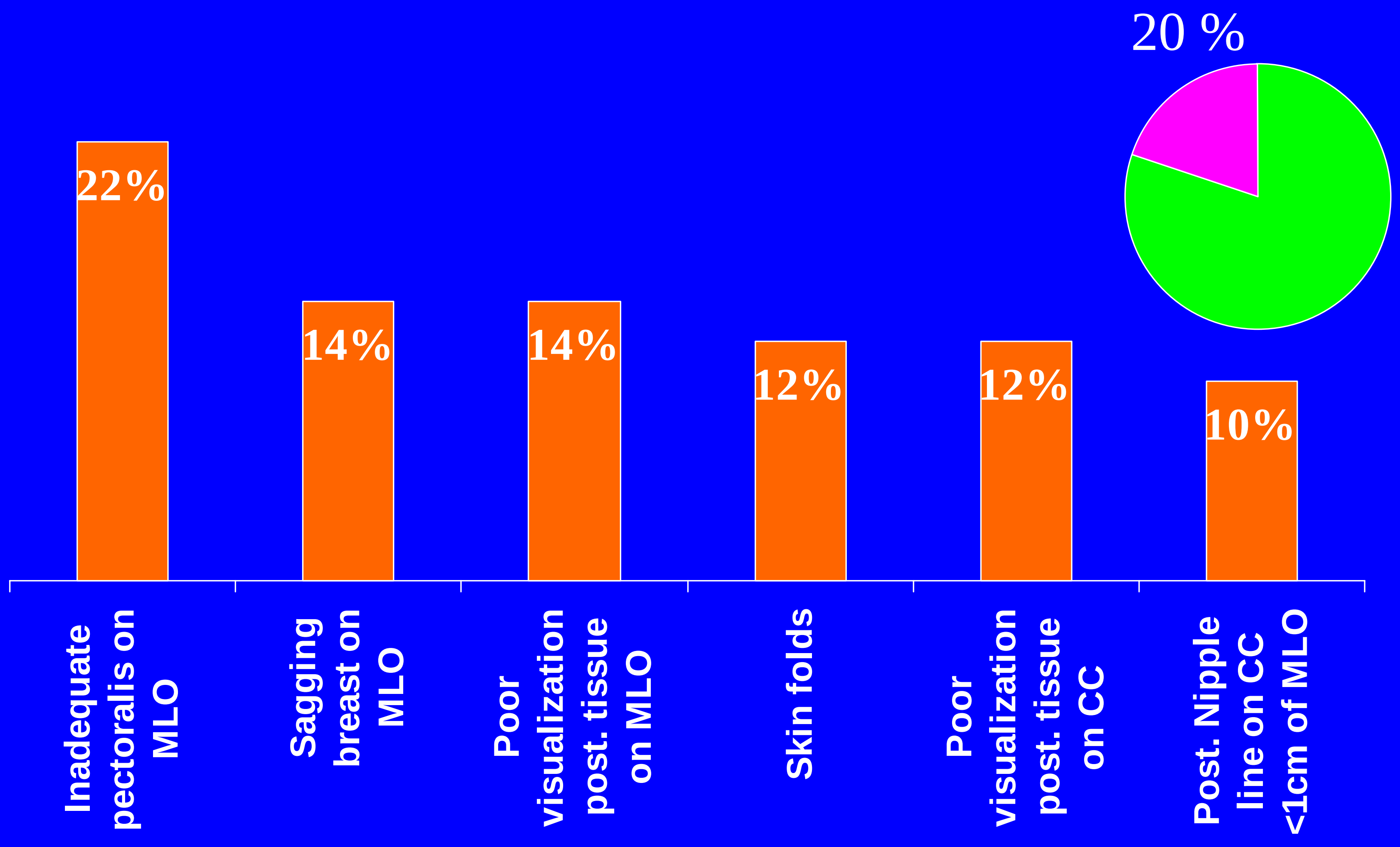
Clinical Image Failures : 1997*

- Positioning 20%
- Exposure 15%
- Compression 14%
- Sharpness 13%
- Contrast 13%
- Artifacts 11%
- Labeling 8%
- Noise 5%



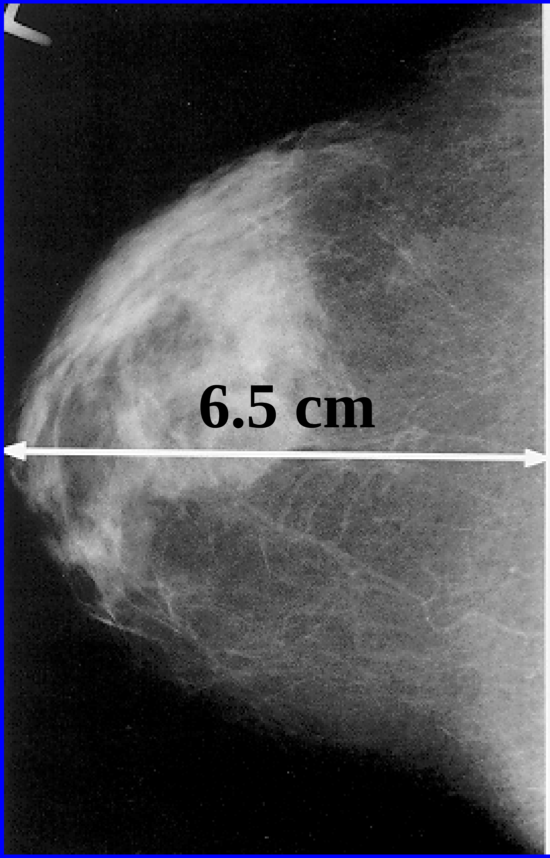
*Bassett, et al;Radiology 2000;215:698-702

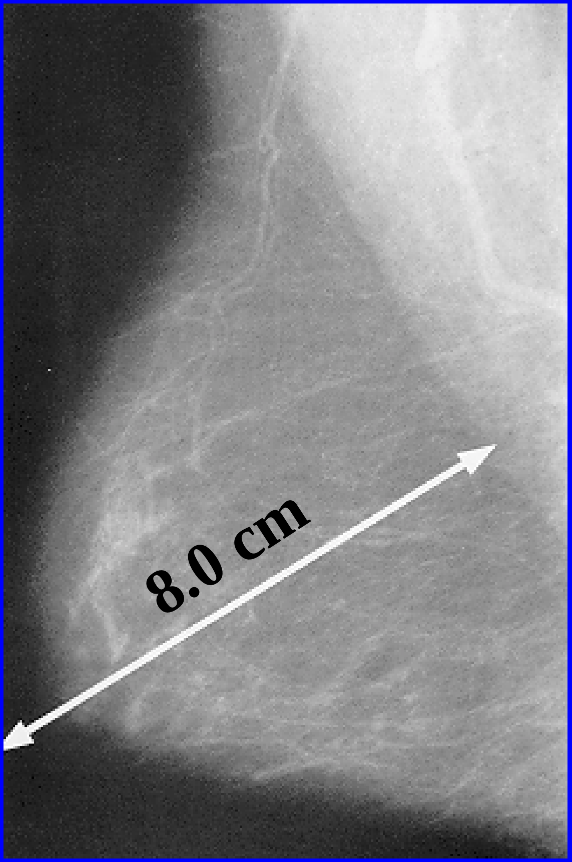
Positioning Problems : 1997*



*Bassett, et al; Radiology 2000; 215: 698-702

Posterior nipple line on CC not within 1 cm of that on MLO





Mammography Troubleshooting Categories:

- **Film processing**
- **Film-Screen combination**
- **X-ray unit**
- **Technologist technique**

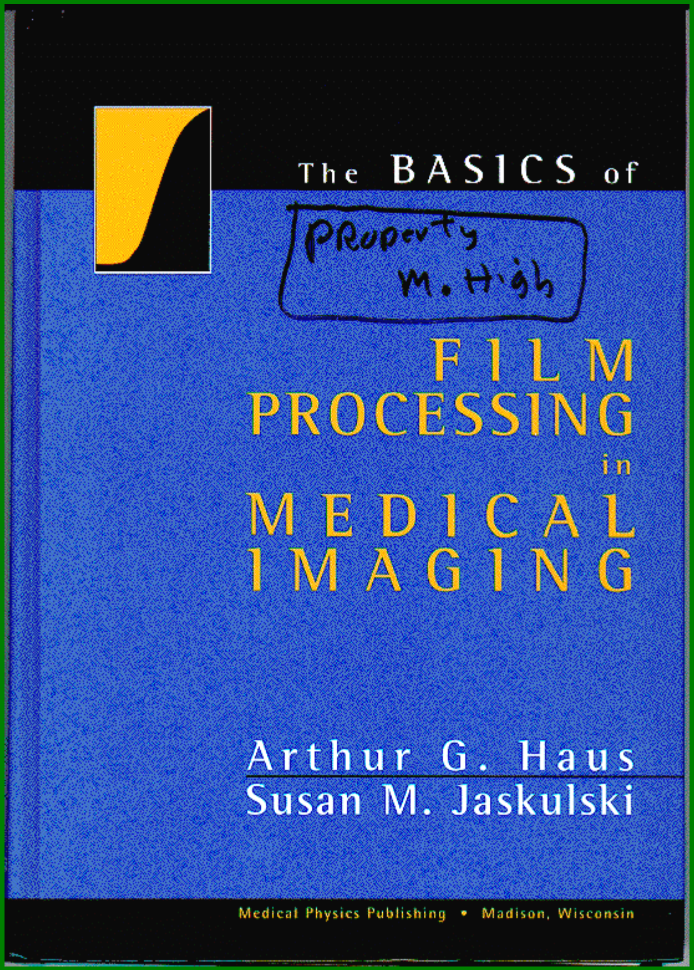
Troubleshooting the Film Processing: General principles

- Film must be processed as recommended by film manufacturer (or equivalently)
  - physicist can compare processing at another site using recommended processing.
- Sensitometry does not guarantee proper processing, only consistency.

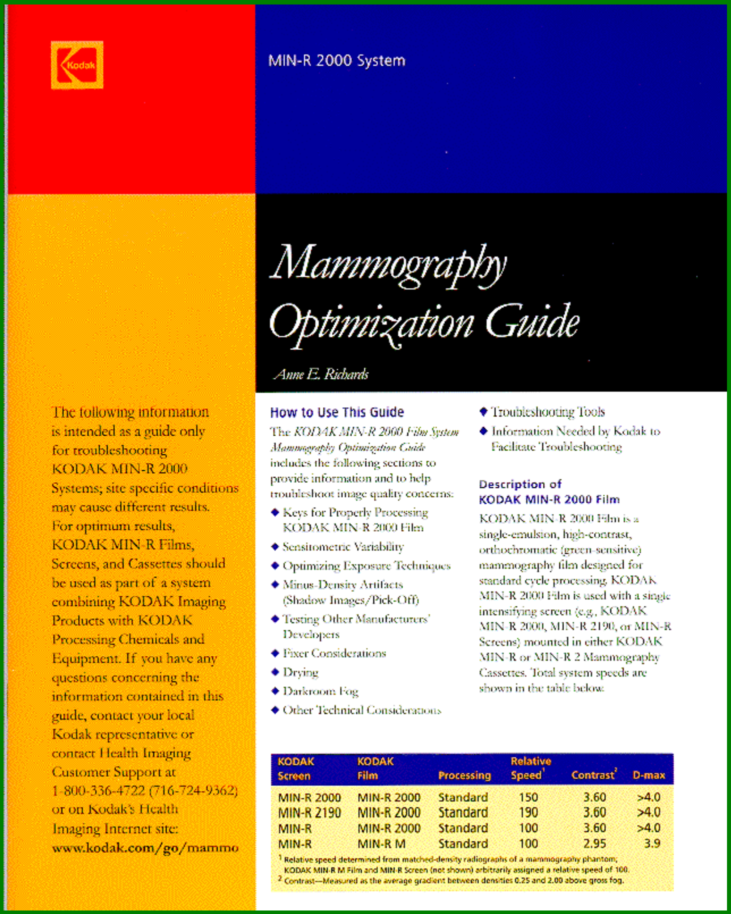
Troubleshooting the Film Processing: General principles

- Look for changes
  - film type, emulsion number
  - chemistry type, supplier, mixer
  - staffing, hours of operation, films/day
  - PM schedule, PM personnel
- Film processing must be evaluated before troubleshooting the x-ray unit

Troubleshooting Resources:



Troubleshooting Resources:



MIN-R 2000 System

Mammography Optimization Guide

Anne E. Richards

The following information is intended as a guide only for troubleshooting KODAK MIN-R 2000 Systems; site specific conditions may cause different results. For optimum results, KODAK MIN-R Films, Screens, and Cassettes should be used as part of a system combining KODAK Imaging Products with KODAK Processing Chemicals and Equipment. If you have any questions concerning the information contained in this guide, contact your local Kodak representative or contact Health Imaging Customer Support at 1-800-336-4722 (716-724-9362) or on Kodak's Health Imaging Internet site: www.kodak.com/go/mammo

How to Use This Guide

The *KODAK MIN-R 2000 Film System Mammography Optimization Guide* includes the following sections to provide information and to help troubleshoot image quality concerns:

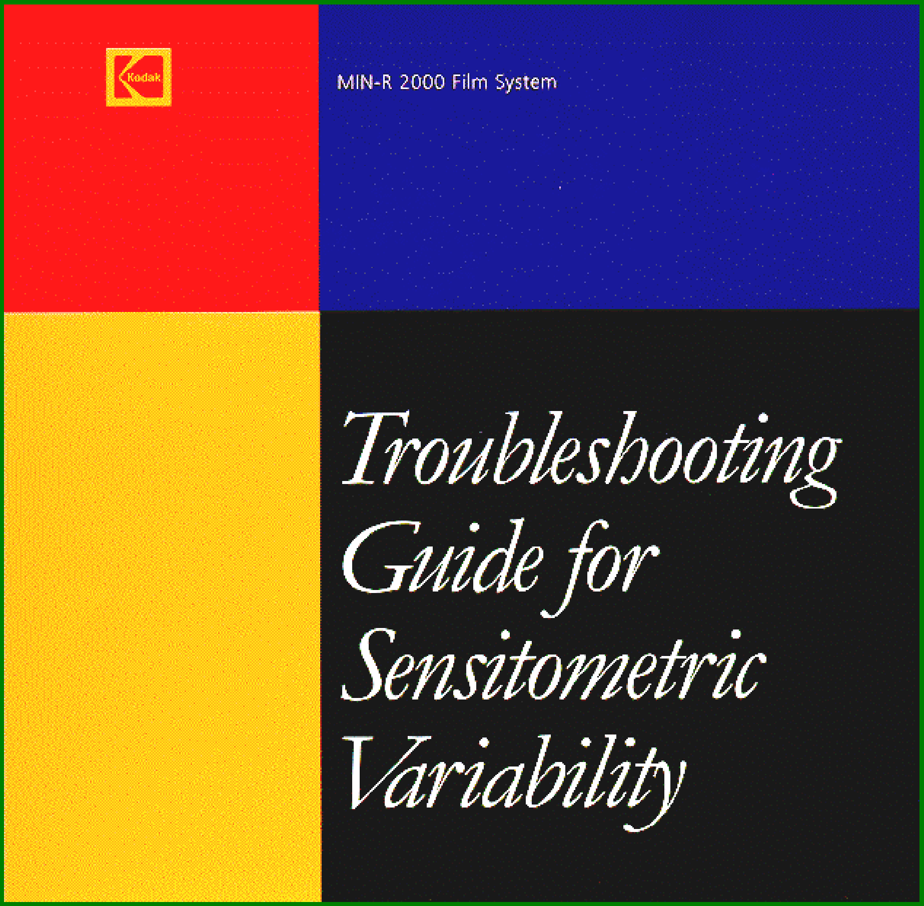
- Keys for Properly Processing KODAK MIN-R 2000 Film
- Sensitometric Variability
- Optimizing Exposure Techniques
- Minus-Density Artifacts (Shadow Images/Pick-Off)
- Testing Other Manufacturers' Developers
- Fixer Considerations
- Drying
- Darkroom Fog
- Other Technical Considerations
- Troubleshooting Tools
- Information Needed by Kodak to Facilitate Troubleshooting

Description of KODAK MIN-R 2000 Film

KODAK MIN-R 2000 Film is a single-emulsion, high-contrast, orthochromatic (green-sensitive) mammography film designed for standard cycle processing. KODAK MIN-R 2000 Film is used with a single intensifying screen (e.g., KODAK MIN-R 2000, MIN-R 2190, or MIN-R Screens) mounted in either KODAK MIN-R or MIN-R 2 Mammography Cassettes. Total system speeds are shown in the table below.

KODAK Screen	KODAK Film	Processing	Relative Speed[1]	Contrast[2]	D-max
MIN-R 2000	MIN-R 2000	Standard	150	3.60	>4.0
MIN-R 2190	MIN-R 2000	Standard	190	3.60	>4.0
MIN-R	MIN-R 2000	Standard	100	3.60	>4.0
MIN-R	MIN-R M	Standard	100	2.95	3.9

[1] Relative speed determined from matched-density radiographs of a mammography phantom; KODAK MIN-R M Film and MIN-R Screen (not shown) arbitrarily assigned a relative speed of 100.
[2] Contrast—Measured as the average gradient between densities 0.25 and 2.00 above gross fog.



Troubleshooting Resources:

Mammography Troubleshooting Categories:

- **Film processing**
- **Film-Screen combination**
- **X-ray unit**
- **Technologist technique**

Troubleshooting the Film-Screen Combination: High system speed

- **Analysis of 31,000 phantom images submitted to ACR showed:**

  High failure for masses & fibers (30-40%) associated with doses lower than 0.75 mGy (Haus, Yaffe, Feig, et al. 2000)
- **Low doses should trigger a careful evaluation of image noise.**

Troubleshooting the Film-Screen Combination: Low System Speed

- May result in blur due to long exposure times
- May result in low contrast if kVp is raised to achieve proper exposure times
- Dose and risk may be needlessly high.

Average Glandular Dose:

- **An important troubleshooting tool**
- **It should be within an appropriate range**

Mammography Troubleshooting Categories:

- Film processing
- Film-Screen combination
- X-ray unit
- Technologist technique

Troubleshooting the Mammographic X-Ray Unit:

- Physicist may feel this is an easy category
  - Make a few measurements
  - Compare with last report
  - Voila! The offending parameter pops out.

- Things are seldom so simple

Example: Troubleshooting AEC because of Low OD on Images

- Seldom fruitful to have service change AEC calibration without determining reason for low OD

- Need a troubleshooting algorithm

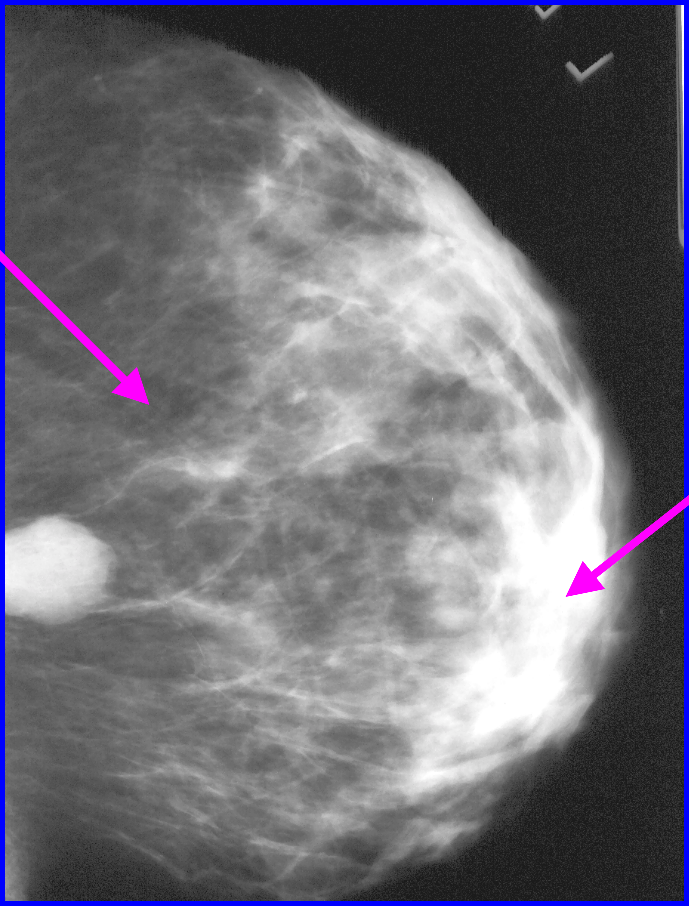
Troubleshooting Low OD: A possible algorithm

First, get the facts:

- **Under what conditions were images light?**
  - **All images, parts of images, dense, fatty, thick, thin, high kVp, Rh filter, large Bucky only, etc**
- **Was there any correlation with**
  - **x-ray unit, cassette #, technologist, radiologist, time of day, day of week, PM schedule, etc**

Areas of film with OD < 1.0 are UNDER-EXPOSED

OD = 1.6



OD = 0.4

Troubleshooting Low OD: A possible algorithm

Next, check film and film processing:

- Nothing can be learned about AEC if processing is not in control
- Any film, chemistry, processing changes?
- Review sensitometry records
- Is processing in control today so AEC testing will be meaningful?

Troubleshooting Low OD: A possible algorithm

Next, check phantom image QC records:

- **Has mAs been stable indicating stability of AEC?**
- **Review phantom OD plot for stability**
- **If there are changes, are they correlated with changes in film sensitometry?**
- **If needed, go back to original images.**

Troubleshooting Low OD: A possible algorithm

Next, review technologist technique:

- **Check Technique chart**
- **Query all technologists about AEC modes used, filters chosen, sensor positioning**
- **Compression adequate to spread tissue?**
- **Physicist needs working knowledge of the various modes available on machine.**

Troubleshooting Low OD: A possible algorithm

Review inputs used by AEC:

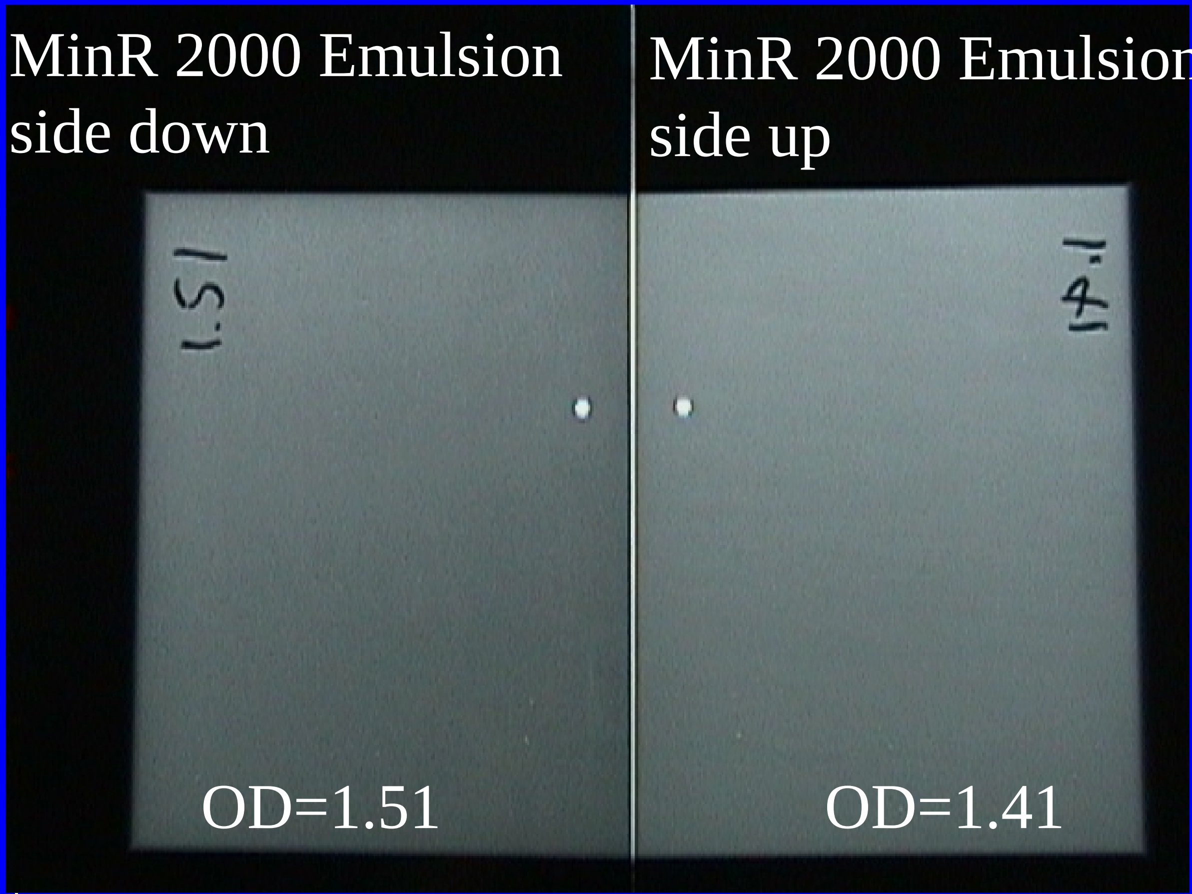
- Thickness (position of compression paddle)
- Compression force
- kVp
- mA, exposure time
- Attenuation measurements (test pulse)
- Film type selected
- Dose or time mode chosen

Troubleshooting Low OD: A possible algorithm

Now expose some phantoms:

- **Simulate patient exposure by using normal compression force with normally used AEC mode.**
- **Process films as technologists do**
  - **emulsion down**
  - **lengthwise on right side of feed tray**

Film must be fed properly



Troubleshooting Low OD: A possible algorithm

Analyze the data:

- What is the proper OD?
  - Phantom > 1.4, Patient >1.0 in densest portion
- But, Depends on
  - type of film
  - viewbox luminance
  - radiologist

Troubleshooting Low OD: A possible algorithm

Finally review all information and make recommendations:

- **There may be more than one cause.**
- **Areas of possible improvement unrelated to the light films may be uncovered.**
  - **Make recommendations concerning these**

LESSON LEARNED #1

Troubleshooting in mammography generally involves several problem sources.

They all need to be considered.

LESSON LEARNED #2

The medical physicist must be knowledgeable about mammography equipment design and how it is used clinically.

LESSON LEARNED #3

The medical physicist must develop a logical and efficient troubleshooting algorithm.

Troubleshooting Decision Trees:

- Identify the particular image quality problem.
- Make a list of the possible causes or contributing factors.
- Create a decision tree algorithm to test causes.

Sensitometry Density and/or Density Difference Change:

- Film emulsion # (use reserved film)
- Developer temp
- Immersion time
- Replenish rates
- Contaminated dev.
- Improperly mixed developer.
- Change in developer type/brand
- Oxidized developer
- Expired/improperly stored film

Sensitometry Base + Fog Increase

- **Contaminated developer**
- **Expired/improperly stored film**
- **Improper safelight**
- **Light leak**

Phantom OD or Contrast Change

- **Film emulsion # (use clinical film)**
- **See all items for sensitometry**
- **AEC calibration or setting**
- **kVp calibration or setting**
- **Target/filter setting**
- **Cassette/screen changed**
- **Position of phantom & AEC sensor**

Phantom mAs Change

- AEC calibration or setting
- kVp calibration or setting
- Target/filter setting
- Cassette/screen changed
- Position of phantom & AEC sensor

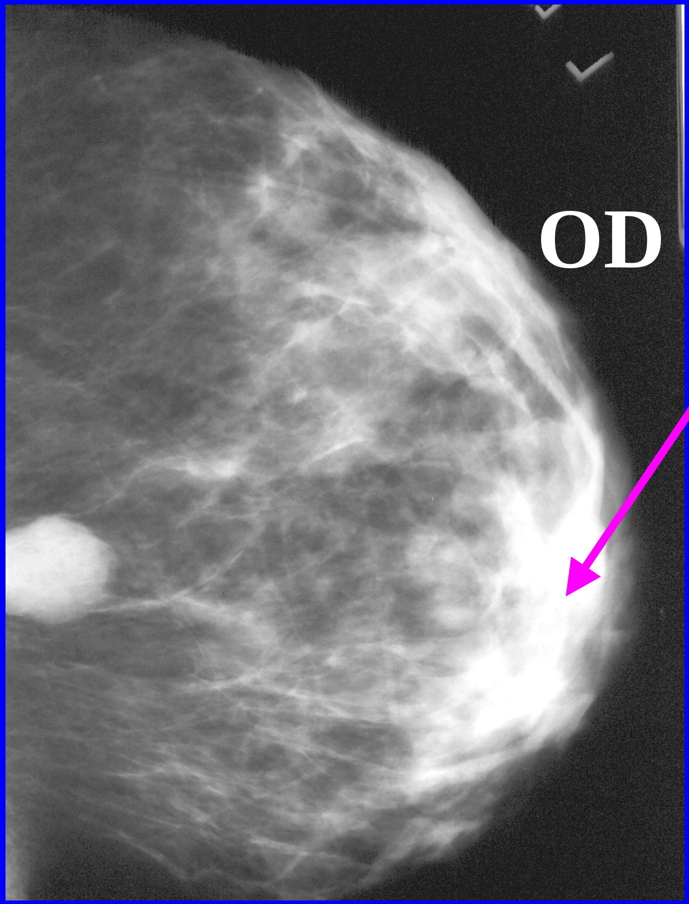
Phantom Score Change

- See all items for sensitometry
- See all items for Phantom OD or Contrast change
- Excessive artifacts
- See items for low contrast, blur and noise

Low Contrast on Patient Images

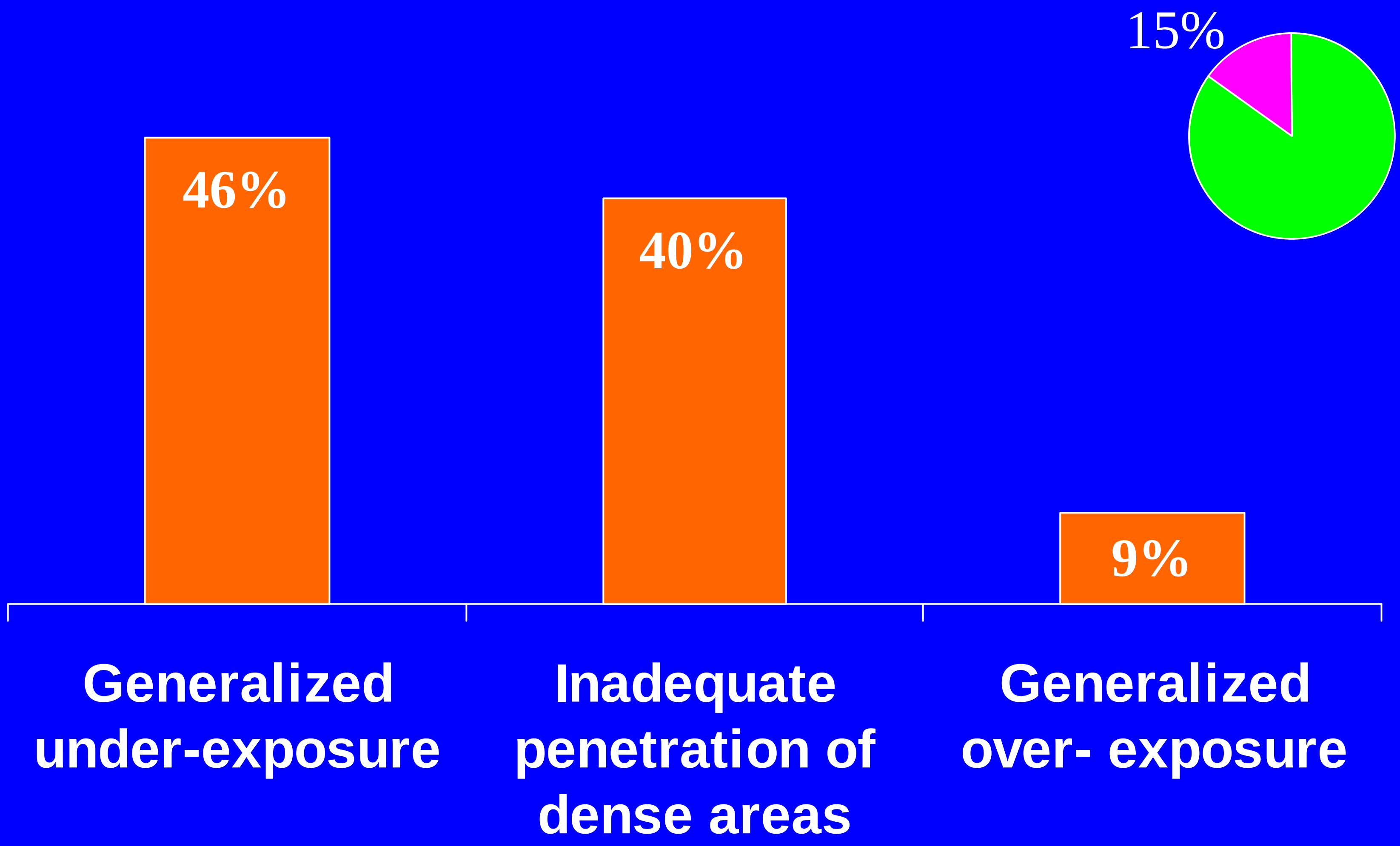
- Most common cause generalized under-exposure, or under-penetration of dense portions of breast

- AEC sensor not under densest portion of breast.



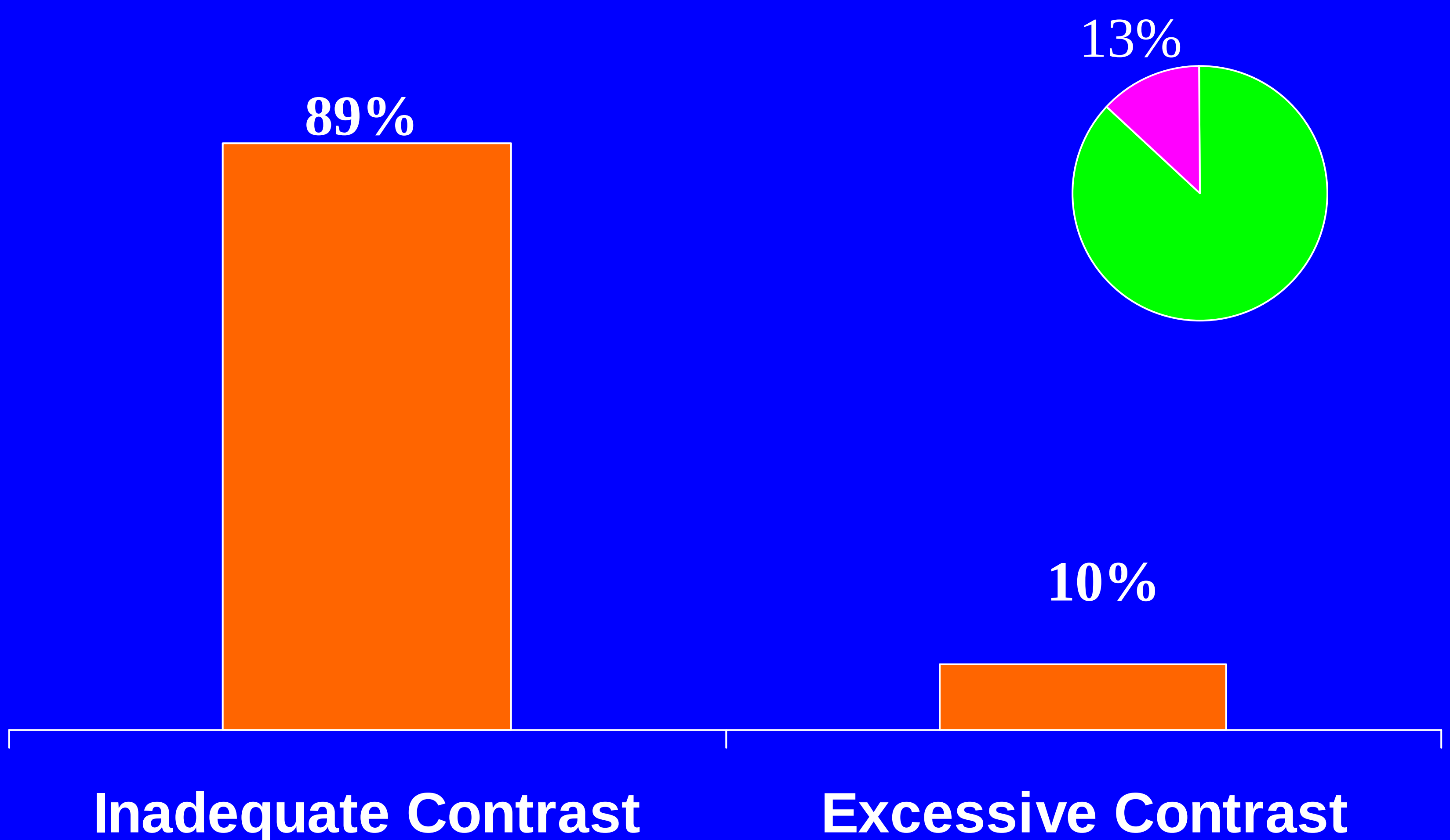
OD = 0.4

Exposure Problems : 1997*



*Basset,et al;Radiology 2000;215:698-702

Contrast Problems : 1997*



*Bassett,et al;Radiology 2000;215:698-702

Low Contrast on Patient Images

- See all items for sensitometry
- See all items for Phantom OD or Contrast change
- High fog level
- Film processing does not meet manufacturer's recommendations

Low Contrast Case Study #1

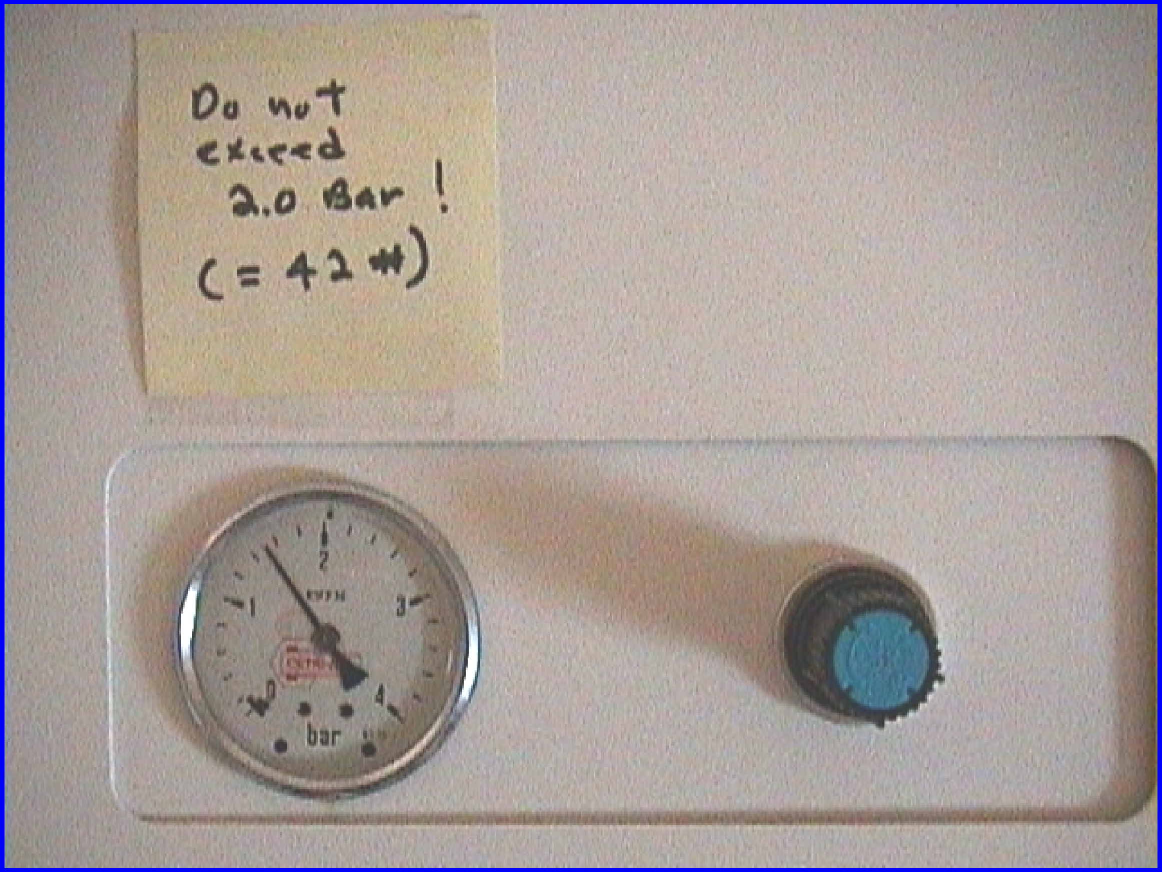
Chemistry changed to non film manufacturer by department manager, but not caught by sensitometry or phantom tests because mistakes were made in plotting.

Non-optimal film processing.

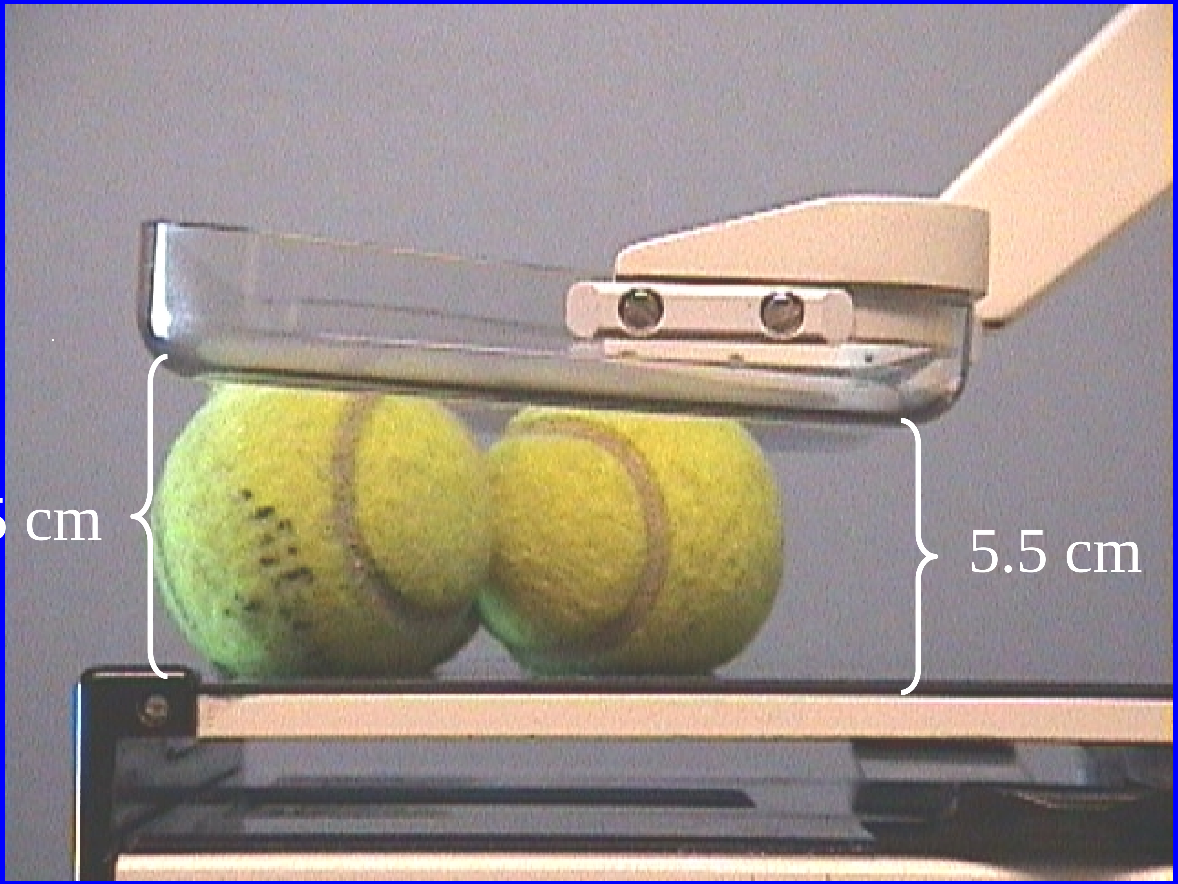
Low Contrast on Patient Images

- kVp calibration or setting (may be affected by AEC mode)
- AEC calibration or setting leading to low OD (may affect kVp or target/filter)
- Target/filter setting (may be affected by AEC mode)
- Inadequate compression

Compression Force is often operator adjustable



Deflection Should be < 1 cm



6.5 cm

5.5 cm

Low Contrast Case Study #2

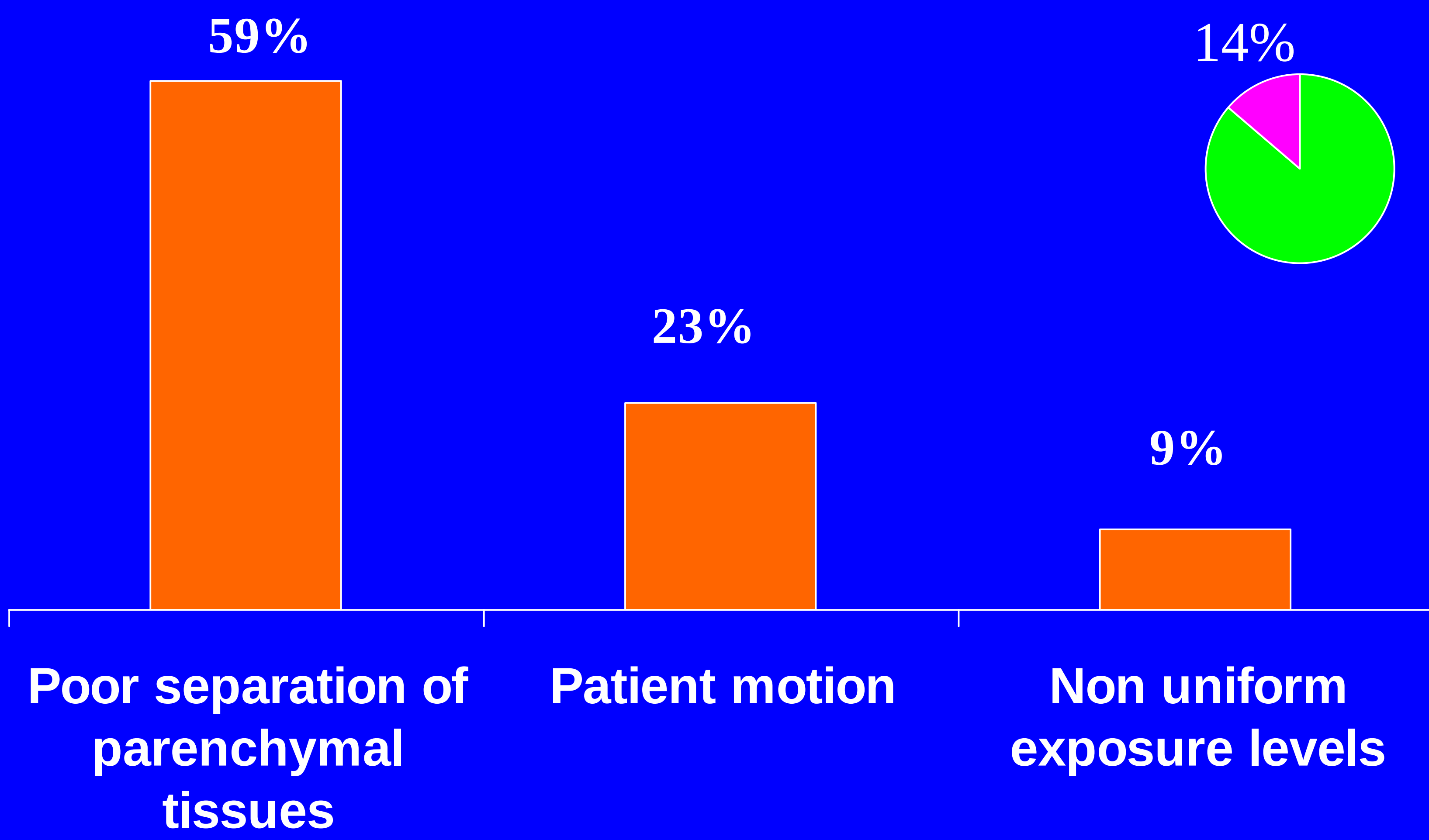
Compression force miscalibrated, indicated 20 dN, measured <25 #

Resulted in 9 cm compressed thickness (compared with 5 cm previous year) and AOP changed filter to Rh.

Excessive Blur on Patient Images

- Marginal focal spot performance
- Inadequate compression (at least 25#, but as much as possible)
- Long exposure times (kVp may be too low) time should be between 1 - 2 sec.
- Poor film-screen contact

Compression Problems : 1997*



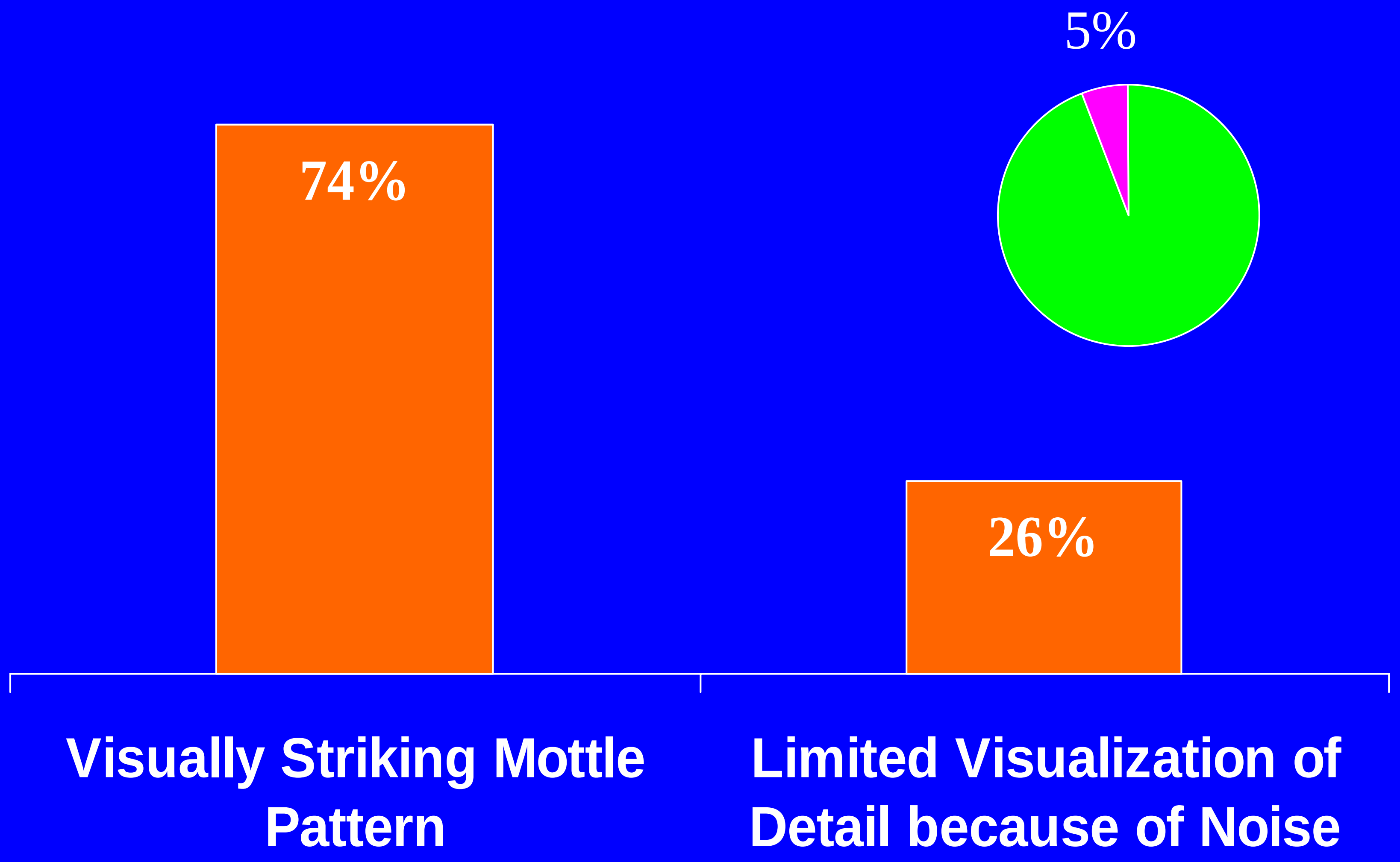
*Bassett, et al; Radiology 2000; 215: 698-702

Excessive Noise on Patient Images

- Film-screen combination too fast
- Correlates with low Average Glandular Dose
- Film processing does not meet manufacturer's recommendations

  (this is a special concern in case of non-dedicated processor)

Noise Problems : 1997*

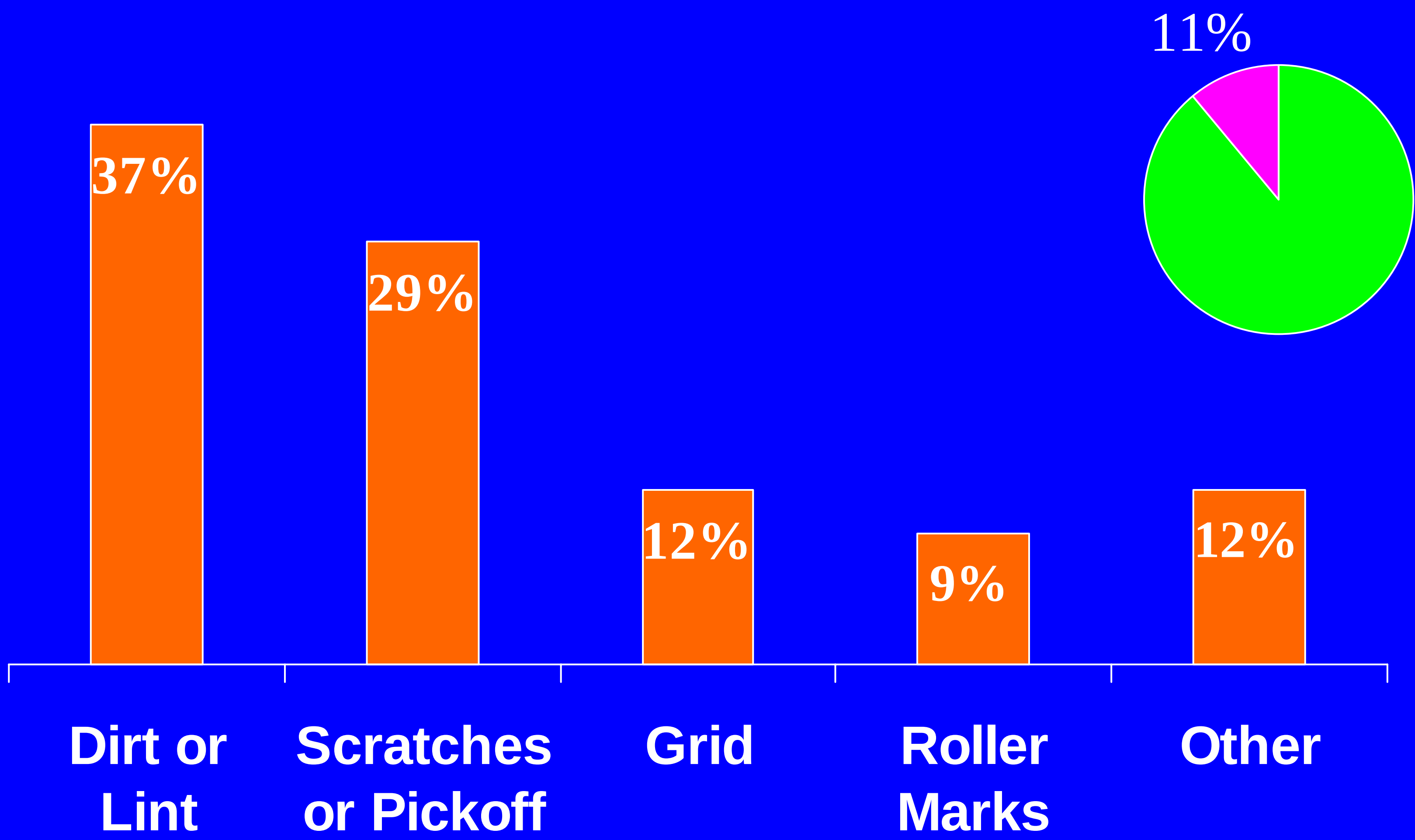


*Bassett, et al; Radiology 2000; 215: 698-702

Excessive Artifacts on Patient Images

- **X-ray unit filter**
- **Screen artifacts**
- **Film handling**
- **Darkroom dust**
- **Improperly installed or vented processor**
- **Dirty/worn or misaligned rollers**
- **Nightly cleaning of cross-over rollers**
- **Not following manufacturer's recommendations for processing**

Artifact Problems : 1997*



*Bassett, et al; Radiology 2000; 215: 698-702

Mammography Troubleshooting Categories:

- **Film processing**
- **Film-Screen combination**
- **X-ray unit**
- **Technologist technique**

Technologist skill affects image quality:

- Responsible for positioning & compression
- Controls OD by AEC sensor positioning
- Controls contrast by kVp and target/filter selection
- Controls motion blur (exposure time) by kVp selection

Compression is one of most important image quality factors

- Separates structures within breast
- Reduces thickness of breast
  - more uniform OD
  - less motion
  - shorter exposure time
  - reduced geometric blur

Physicist can & should evaluate compression

- Is compression force properly set and calibrated?
  - Physicist should perform test personally and compare with technologist's records
- Does compression force hold for length of time it takes to complete patient exposure?

Physicist can & should evaluate compression

- Is compression mode used properly by technologist?
  - Some units have programmable, multi-step compression modes, that if not understood, can result in incomplete compression.

Physicist can & should evaluate compression

- Is the technologist using adequate force?
  - Many units print compression force on the film or on a sticker
  - The physicist should review patient films to see that at least 25# of force is being applied.

kVp controls both contrast and exposure time

RULE of THUMB

Maximize contrast by selecting the lowest kVp consistent with an exposure time between 1 and 2 sec to reduce motion blurring.

kVp controls both contrast and exposure time

- Is the technologist using a kVp which properly balances contrast and time?
- Review auto-kVp AEC modes used with technologists and explain their influence on kVp
- Review exposure times on films
- Consult technique charts

Technique charts are valuable

- Is technique chart conspicuously posted?
- If not, images may not be consistent among all technologists.

- Is technique chart current?
- Chart may not have been changed to reflect changes in screen/film/chemistry

Technique charts are valuable

- Do all technologists follow chart?
- Need to query all technologists.

- Are recommended settings appropriate?
- Do AEC phantom tests result in an acceptable exposure time and kVp?

Mammography Image Quality Troubleshooting

- Requires good acceptance and periodic QC testing data
- Requires analysis of entire imaging chain
  - Film processing
  - Film-Screen combination
  - X-ray unit
  - Technologist technique

Mammography Image Quality Troubleshooting

- **The medical physicist needs to expand his/her knowledge and expertise beyond x-ray unit testing to be a more valuable resource for improving image quality.**

My recommended solution to film processing problems:

* May not be FDA approved