Image gently: Image quality and dose assessment in portable CXR in the NICU and PICU before and after implementation of a high-kVp technique

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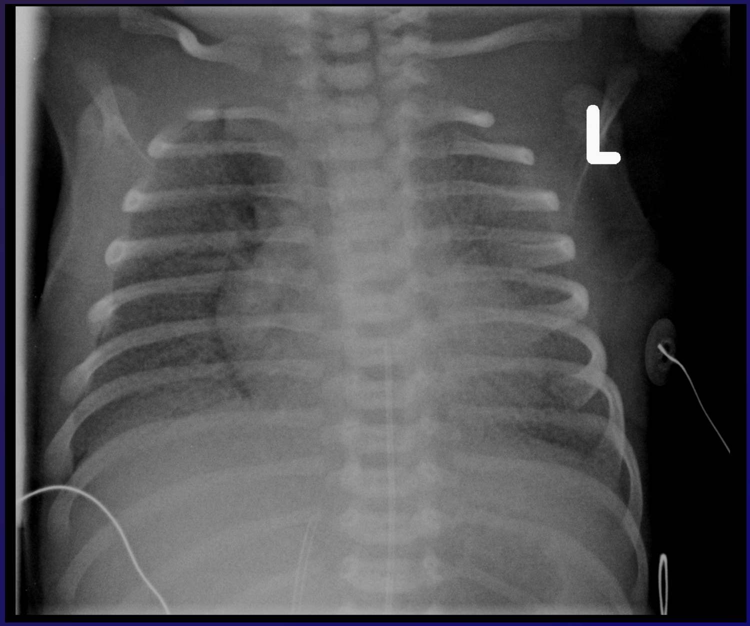
Introduction

- Neonatal radiography is an essential tool in the care of patients in neonatal intensive care units (NICU).
- AP Chest and AP abdomen radiographs are the most common neonatal radiographs.
- Neonatal imaging is commonly carried out using portable radiography.
- Computed radiography (CR) has largely replaced film-screen cassettes in portable neonatal radiography

Introduction

- While neonatal radiography doses are generally low, the exposed population is at higher risk of stochastic effects of radiation

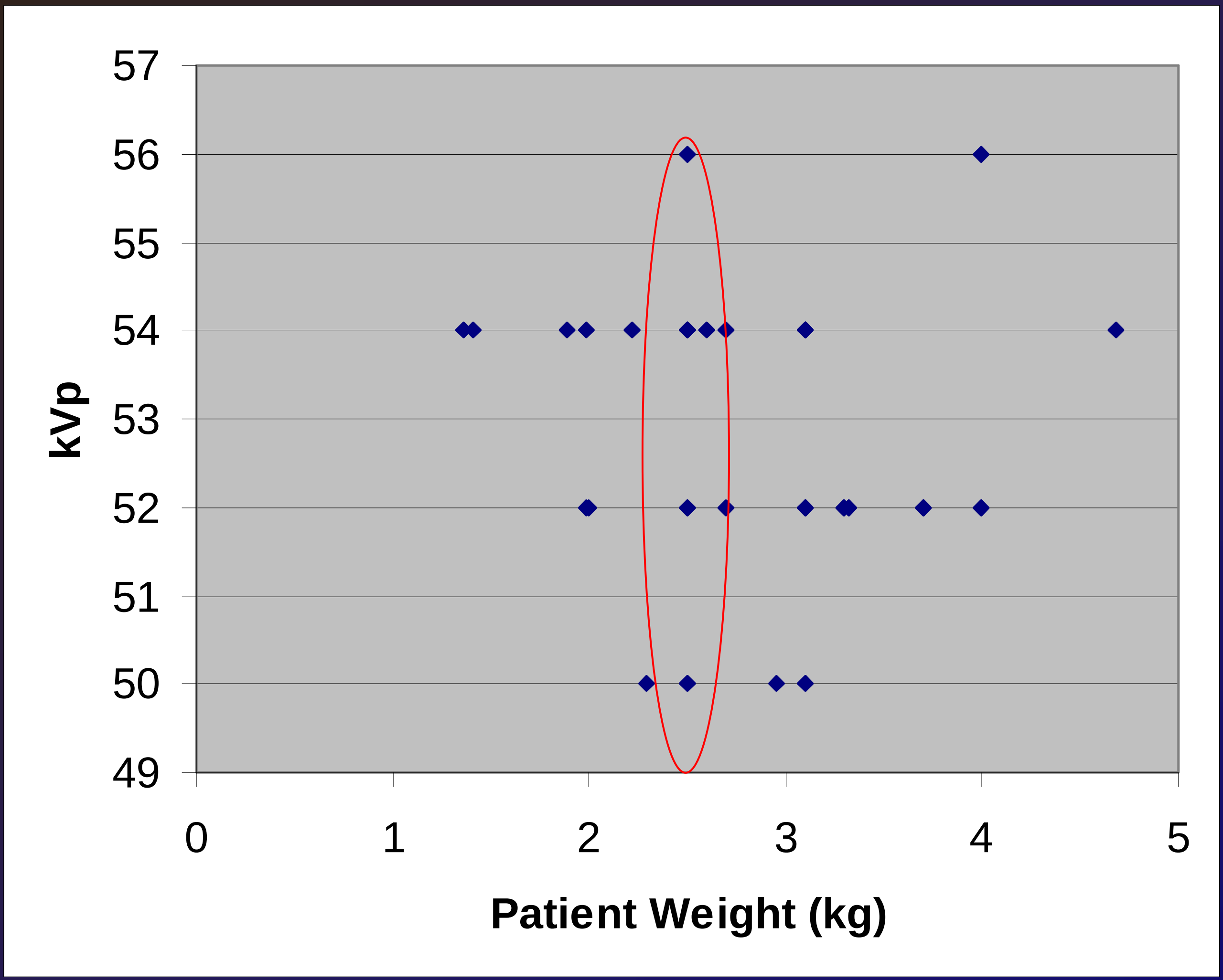
- Quality control and dose surveys are important for assessment of neonatal radiographic practice.



Introduction and Motivation

- Quality control survey of neonatal radiography revealed the following:
  - No standardized technique chart was being followed
  - kVp/mAs and patient doses varied widely, depending on operator experience and training
  - Protocol parameters were not adjusted after introduction of CR. Low kVp (50-56) appropriate for film-screen cassettes still in use.

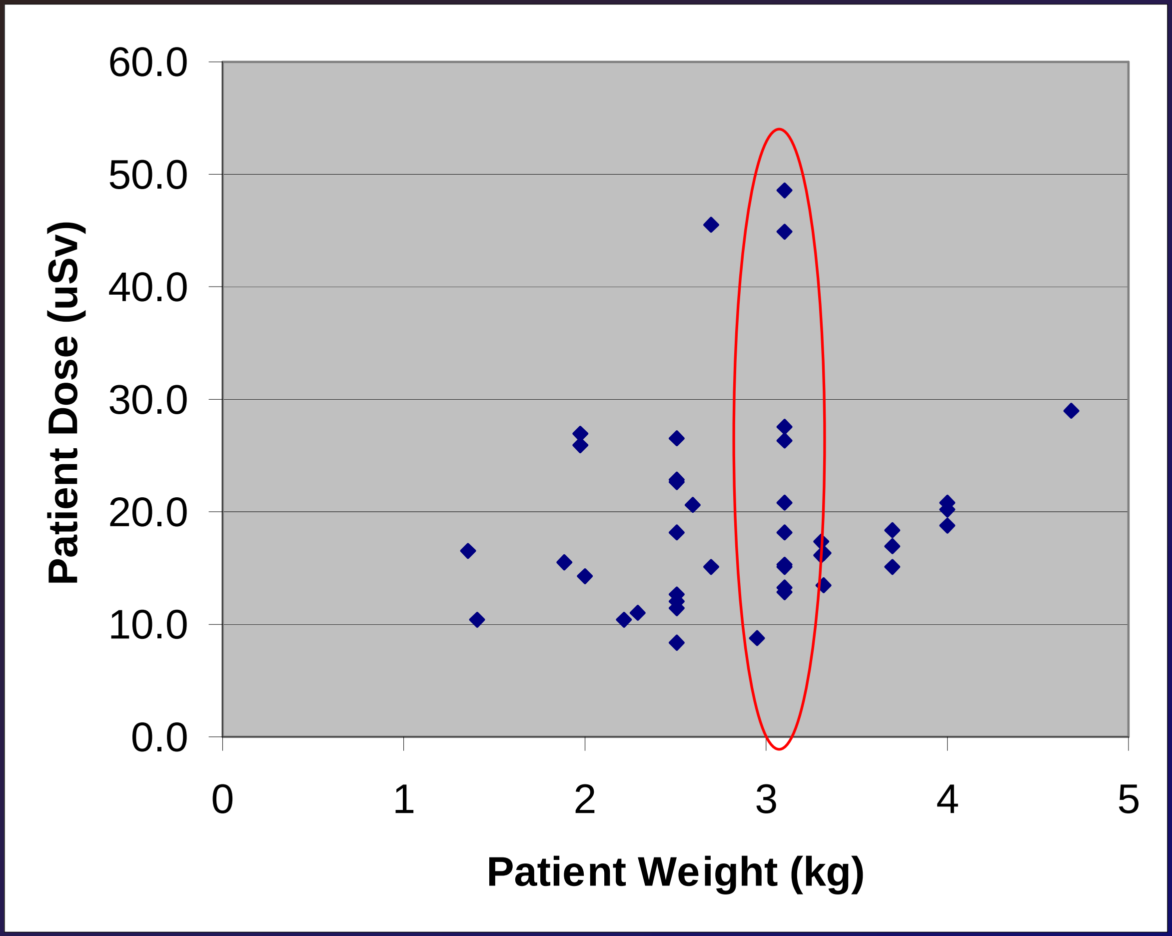
Quality Control Survey



No clear relationship between kVp and patient weight

Wide kVp range for a given weight

Quality Control Survey



Wide range of doses for a given weight highlights the lack of technique standardization

Purpose

- Implement weight-based technique parameters
- Reduce patient dose using a high-kVp technique
- Assess image quality
- Verify that image quality is not compromised

Methods

- Data collection (age, weight, gender, kVp, mAs) at pre-existing conditions for two months.
- Introduction of a weight based high-kVp technique chart
  - Tube potentials - 60 to 76
  - Tube current fixed at 0.5 mAs
- Data collection at new conditions for two months

Methods

- GE AMX4 portable x-ray system
- Fuji CR imaging plates and reader
- Tracked AP chest and abdomen for patients 0-3 months in the NICU and PICU at Hadassah Medical Organization
- Image quality assessment and dose estimation for high and low kVp image sets


זהירות-קרינה מייננת
סוג המקור:
USAID
amx 4
Plus
SID/DFF
SID/DFF

X-ray kVp/mAs for AP Radiographs of Neonates

משקל	kVp	mAs
< 1000 g	60	0.5
1000 g --- 1500 g	64	0.5
1500 g --- 2500 g	66	0.5
2500 g --- 3500 g	68	0.5
3500 g --- 4500 g	70	0.5
4500 g --- 5500 g	72	0.5
5500 g --- 6500 g	74	0.5
> 6500 g	76	0.5

Dose Estimation

- Portable GE AMX4 tube output characterized at various kVp settings
- Incident air kerma measured at 100 cm from x-ray tube using calibrated Pirahna solid state dosimeter (RTI Electronics, Mölndal, Sweden)

Dose Estimation

- Effective dose for each images estimated using PCXMC 2.0 Monte Carlo software
- Software inputs:
  - weight, height, beam area, kVp, incident air kerma, filtration, SID

PCXMC Dose Calculation Software

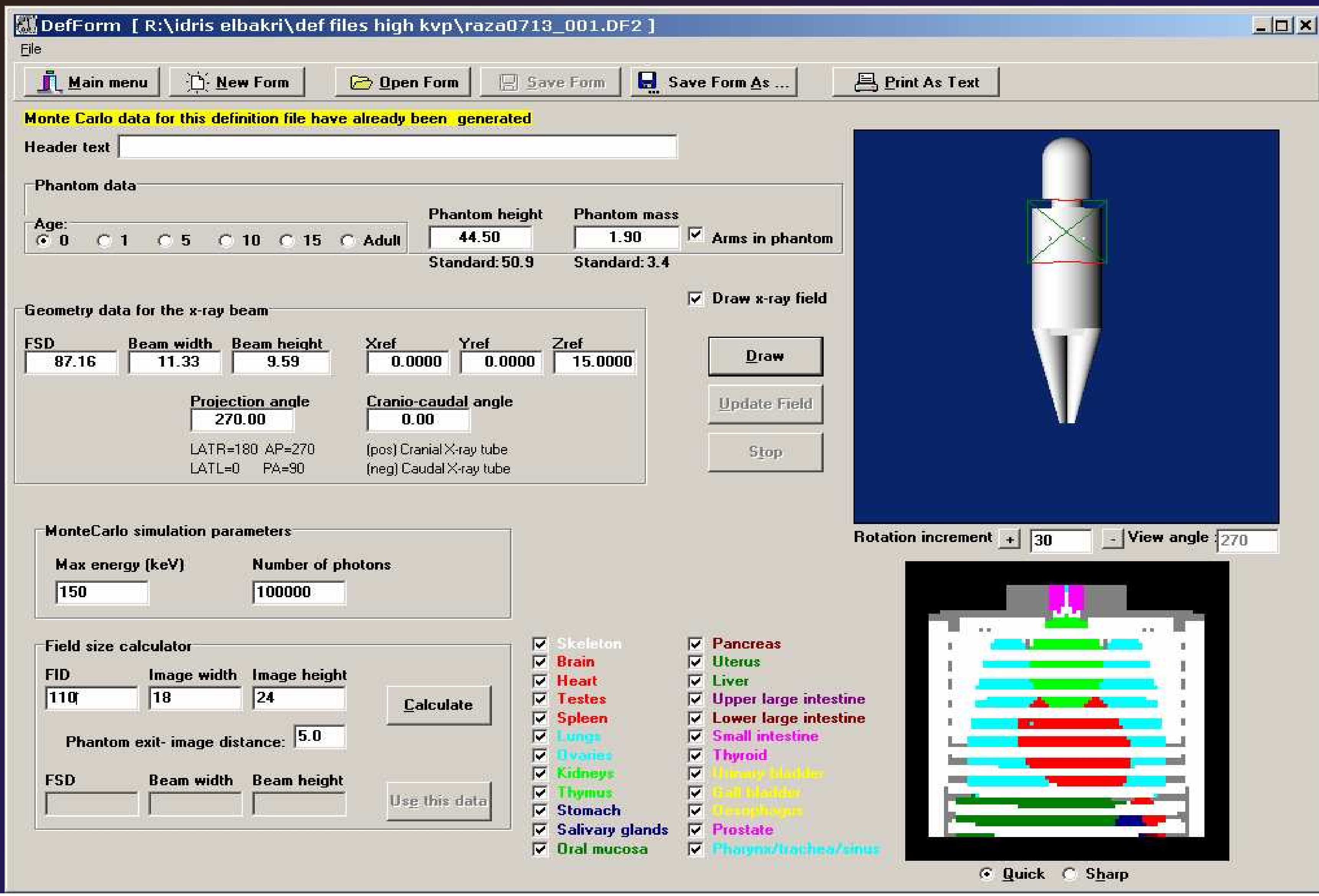


Image Quality Assessment

- Two fellowship-trained pediatric radiologists blindly assessed images before and after technique change.
- Evaluation criteria based on the CEC image quality standards[1]
- Criteria scored on a 4-point scale: (1) criterion definitely not defined, (2) criterion probably not defined, (3) criterion probably defined and (4) criterion definitely defined or (na) not applicable.
- Average score computed for each image

1. European Commission. European guidelines on quality criteria for diagnostic radiographic images in paediatrics. EUR 1626. July 1996.

Image Quality Criteria

- Reproduction of the thorax without rotation and tilting
- Reproduction of the chest must extend from the cervical trachea to T12/L1 (part of the abdomen maybe included for special purposes).
- Reproduction of the vascular pattern in central two-thirds of the lungs
- Reproduction of the trachea
- Reproduction of the proximal bronchi
- Visualization of the mediastinum
- Visibility of the tip of the endotracheal tube
- Visually sharp reproduction of the diaphragm
- Visually sharp reproduction of the costophrenic angles
- Reproduction of the spine
- Visualization of the retrocardiac lung
- Visibility of the tip of the umbilical catheter
- Visibility of the tip of the long line
- Visibility of bowel loops
- Visibility of the nosagastric tube

Statistical Analysis

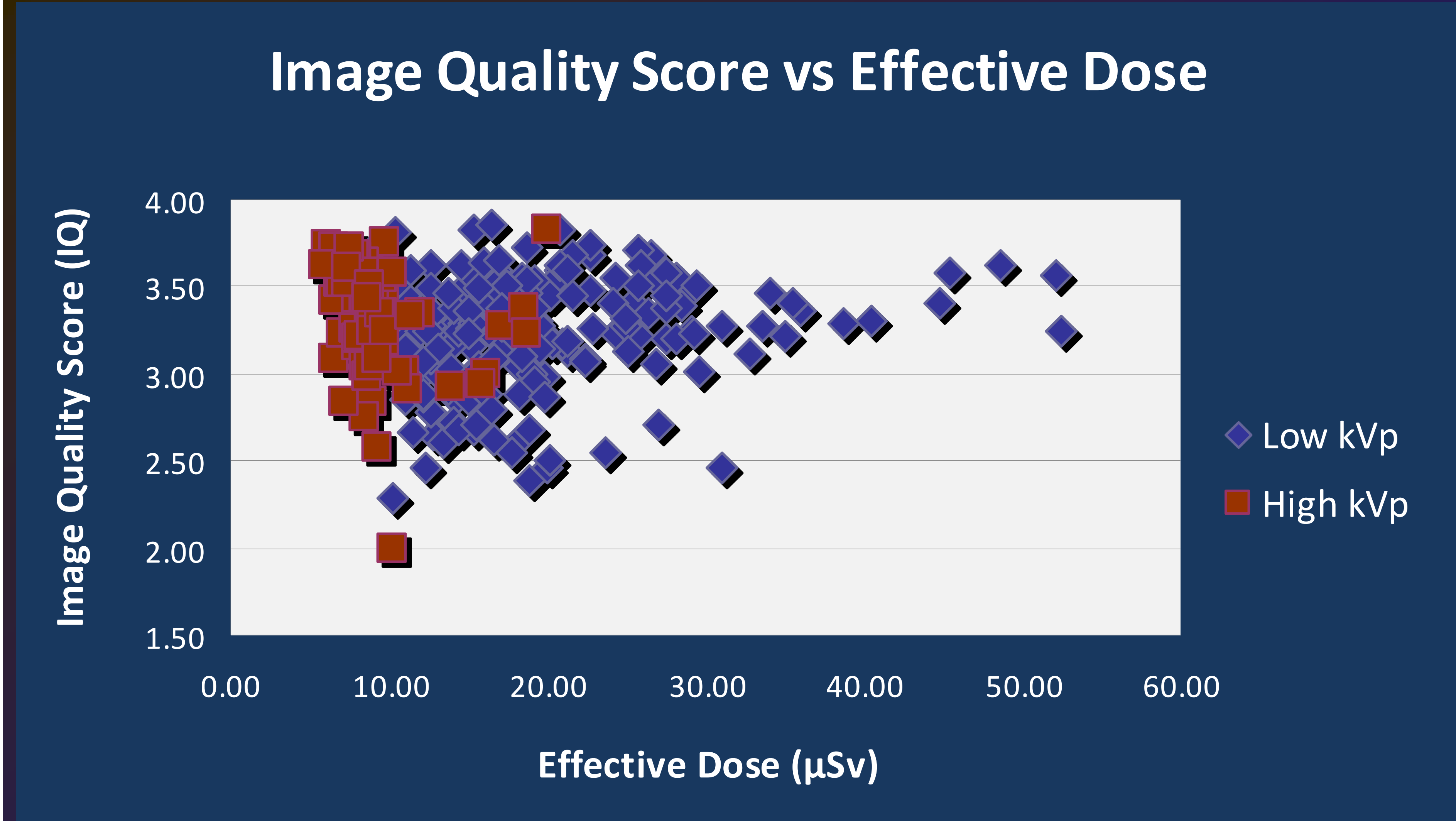
- We used the 2-tailed t-test to check significance of change in:
  - Patient dose
  - Patient weight
  - Reader 1 score
  - Reader 2 score
- We used ANCOVA analysis to check significance of change in effective dose with x-ray protocol, patient age and weight.

Results

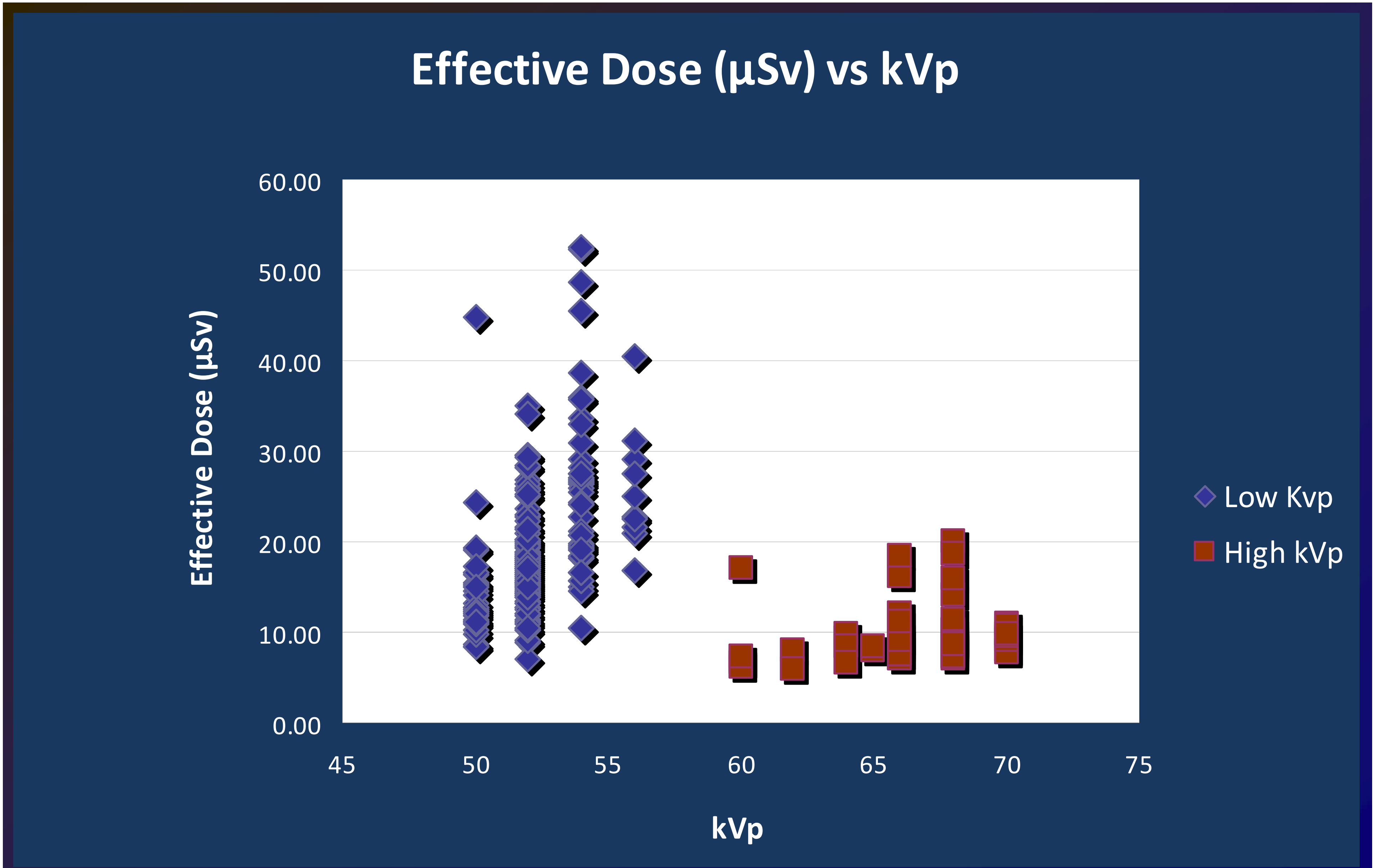
	Number	Percentage %
Gender (M/F)	163/91	63.9/35.7
Chests	221	86.7
Abdomens	32	12.5
Chest/Abdomen	2	0.8
High KVp	61	24
Low kVp	193	76
Total	254	100%

Results - Averages

	kVp	mAs	Effective dose (uSv)	Image quality score
Low kVp N=193	52.6	2.6	19.4±8.0	3.26±0.35
High kVp N=61	65.3	0.53	9.6±3.1	3.35±0.36



Much narrower dose spread with new technique while maintaining similar IQ scores



High-kVp method results in reduced dose and narrower dose range

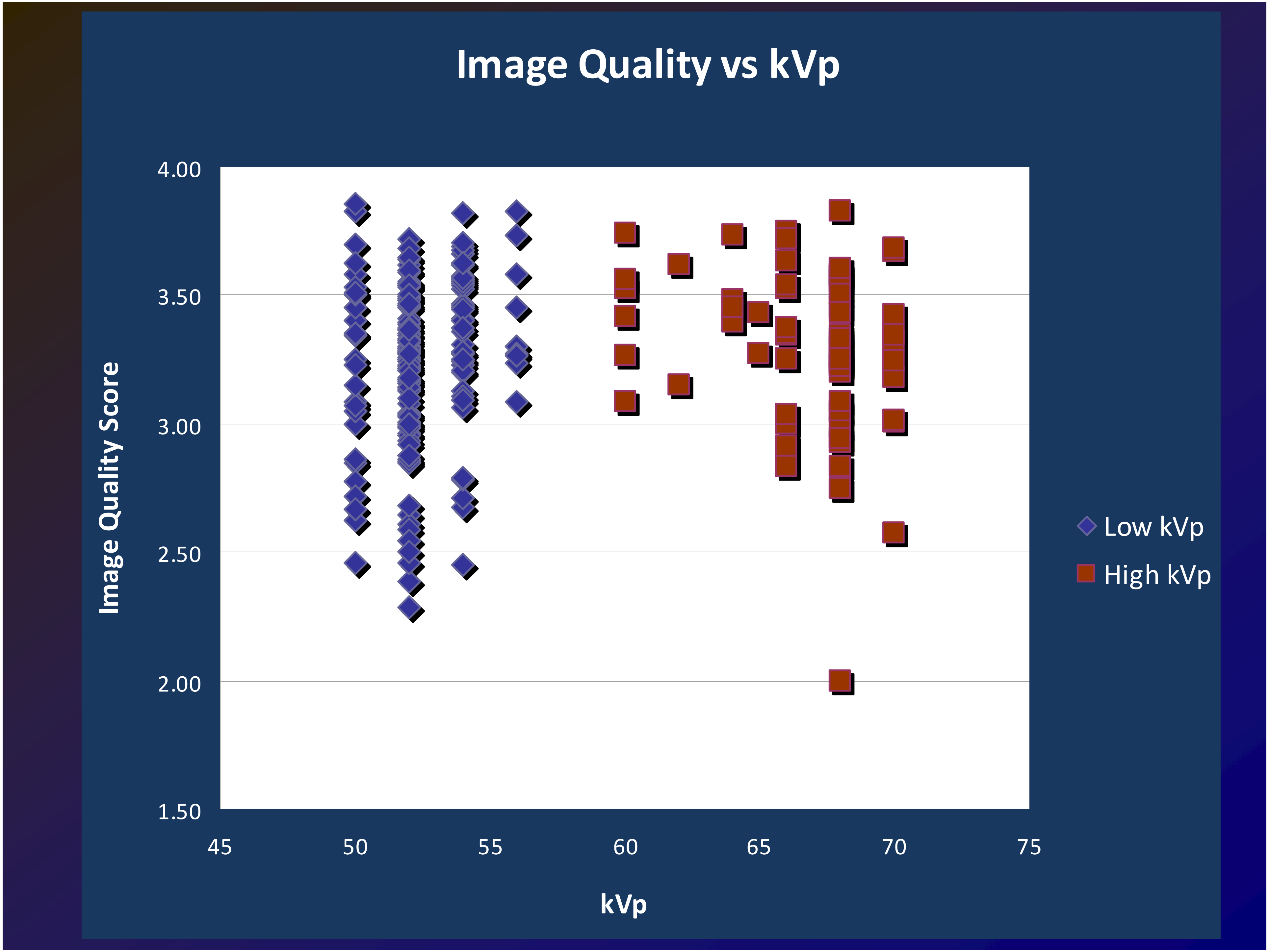
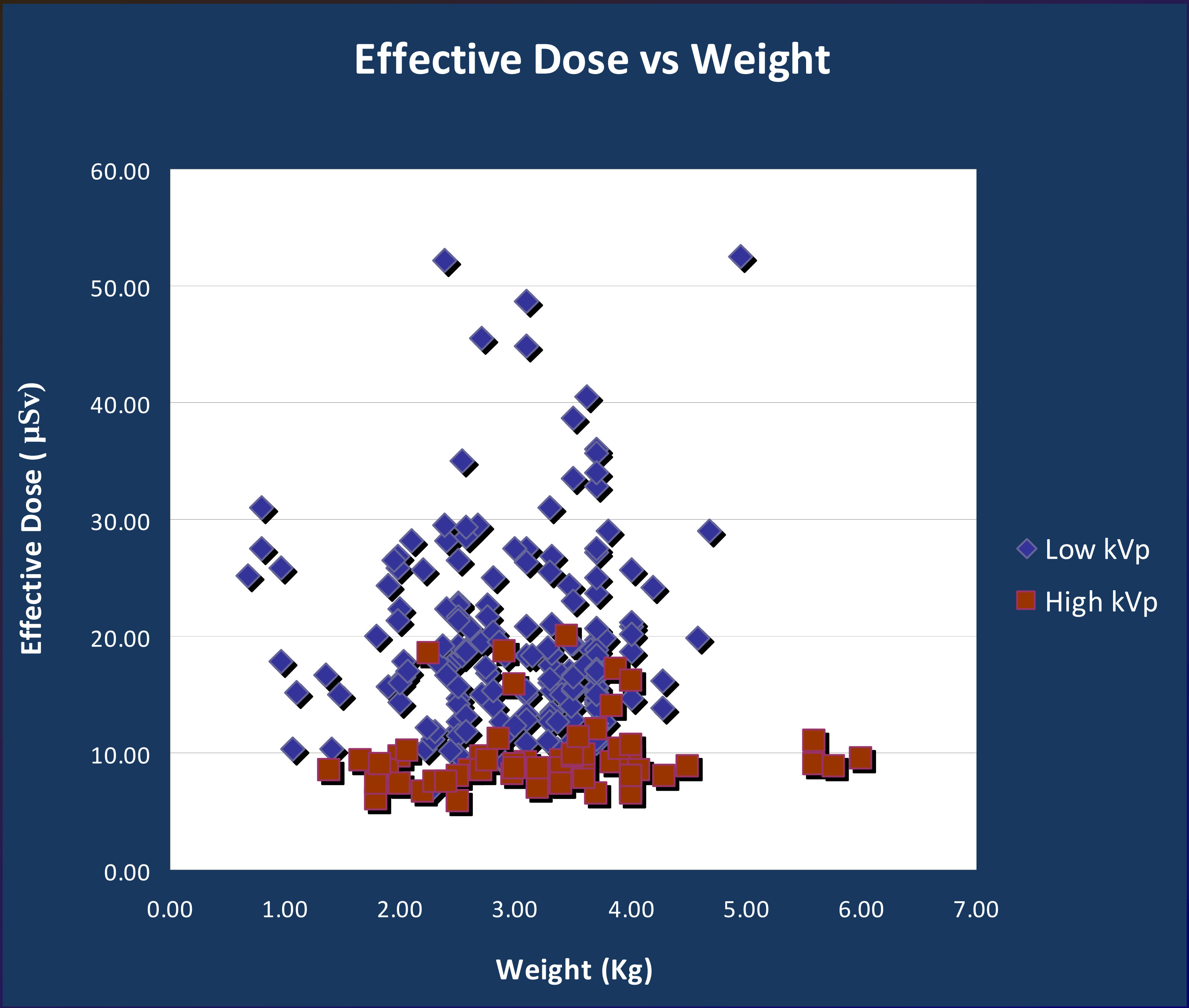


Image Quality vs kVp
Image Quality Score
4.00
3.50
3.00
2.50
2.00
1.50
45
50
55
60
65
70
75
kVp
Low kVp
High kVp



Effective Dose vs Weight
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Effective Dose (µSv)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Weight (Kg)
Low kVp
High kVp

Statistical Analysis

- 2-tailed t-test results:
  - Dose change is significant ($p<-0.0001$)
  - Weight change is insignificant ($p=0.072$)
  - Reader 1 score change is significant ($p=0.04$)
  - Reader 2 score change is significant ($p<0.001$)
- ANCOVA analysis showed that x-ray protocol is the only parameter that effects effective dose significantly ($p<0.0001$)

Summary of Results

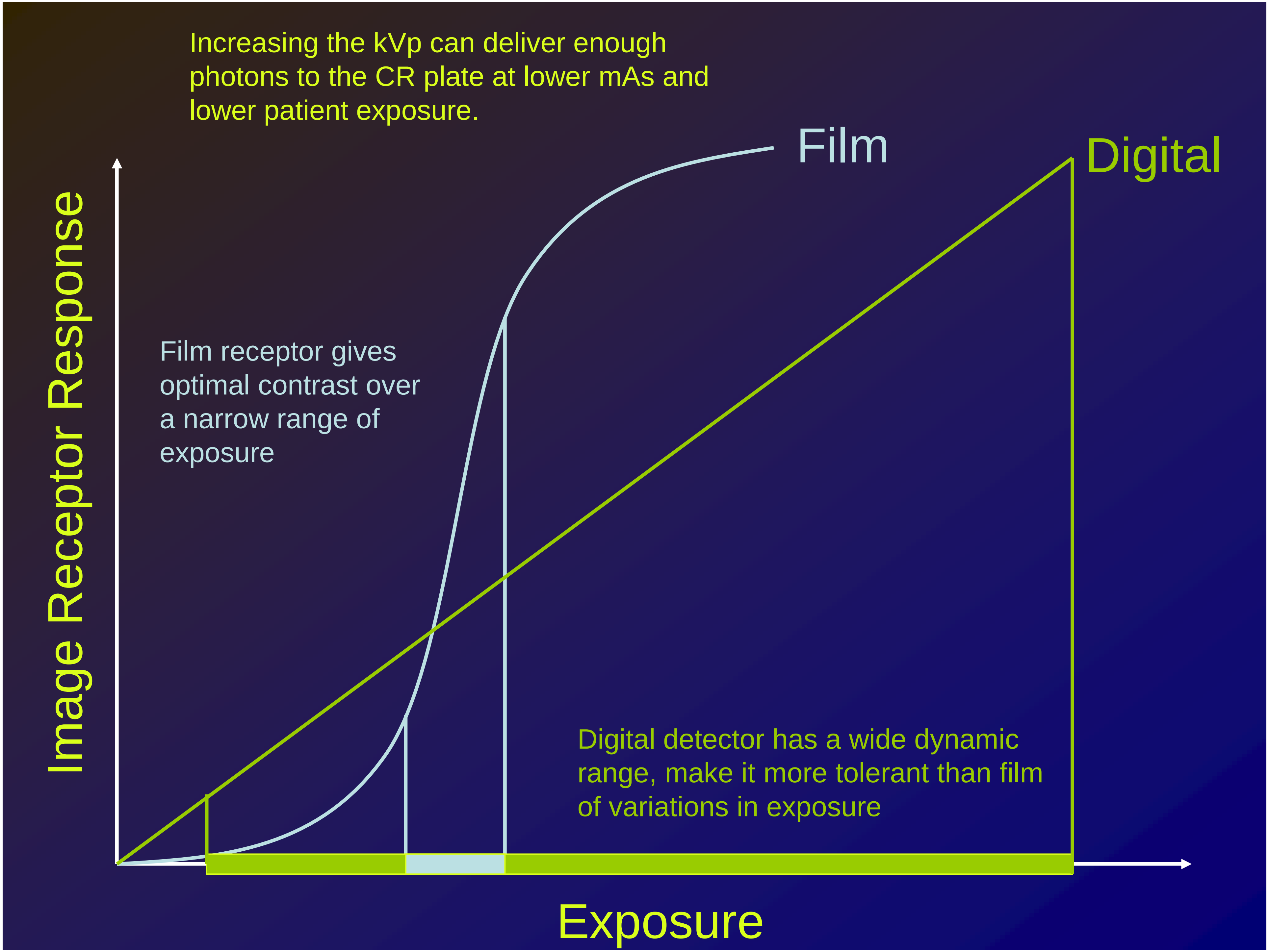
- Clinical image rating is not affected by introducing weight-based higher-kVp technique chart
- Average effective dose reduced by 50%
- Effective dose range reduced from [7.0-52.4] uSv to [5.9 – 19.9] uSv
- The change in protocol parameters is the single most significant factor contributing to dose reduction

Discussion

- Quality control survey revealed that the ALARA principle was not fully applied.
- Lack of standardized technique chart lead to wide variations in patient dose. The same patient could receive doses varying by a factor of 5 for the same examination.
- The dose-saving possibilities of digital imaging were not leveraged.

Discussion – Digital Imaging

- Film imaging is *contrast* limited. kVp choice depends on:
  - Narrow exposure range required by film
  - Beam penetration (requires higher kVp)
  - Subject contrast (requires lower kVp).
- Digital imaging is *noise* limited.
  - Wide range of useful exposure
  - Image Processing enhances image contrast
  - Enough exposure must reach the detector to avoid a noisy image



Increasing the kVp can deliver enough photons to the CR plate at lower mAs and lower patient exposure.
Film
Digital
Image Receptor Response
Film receptor gives optimal contrast over a narrow range of exposure
Digital detector has a wide dynamic range, make it more tolerant than film of variations in exposure
Exposure

Discussion

- High-kVp protocol lowered patient dose significantly and reduced dose variations.
- The ‘significance’ in change in readers image quality scores is due to the narrow range of scores obtained.
- For all practical purposes, image quality not affected by change in kVp.

Conclusions / Lessons Learned

- Periodic quality control results in better patient care.
- “Imaging gently” is a team effort (physicists, radiologists, technologists, administration).
- Technique optimization should be carried out when new imaging modalities and techniques are implemented.

Conclusions / Lessons Learned

- Data is your best friend. We continue to record exposure and patient data for subsequent reviews.
- Data collected in this study will enable us to assess other aspects of quality control, such as positioning and collimation
- High-kV low-mAs technique enables marked dose reduction
- High-kV low-mAs technique dose not impair image quality