Disclaimer and Notices.

- Information had been extracted from Operators Manual and/or Technical Manuals published by various equipment manufacturers (as acknowledged in the slides).
- Parts of the presentation had been shown in the Mini Refresher Courses at the Annual Meetings of the Radiological Society of North America (RSNA) in 2013 and in 2014.
- Publications; American Association of Physicists in Medicine (AAPM) Task Group Report #124, #125 and #190.
- AAPM Task Group Report #190 is currently under the review process in the Science Counsile of AAPM.
- Papers from Medical Physics Journal are referred.
- No Financial Disclosure to Report.
Current Topics in Diagnostic Radiological Physics: Technical Questions Associated with Setting Up Enterprise Wide Patient Radiation Dose Monitoring And Tracking Programs.

Pei-Jan Paul Lin, Ph.D.
Division of Radiation Physics and Biology
Virginia Commonwealth University Medical Center
Richmond, Virginia 23298-0615
[E-mail Address: pjlin@vcu.edu]
(1) Radiation induced skin injuries from fluoroscopic interventional studies and computed tomography examinations have been widely reported in the past decades.

(2) For more than few decades, the radiology community as a whole, including industry and government agencies, has been actively involved in trying to develop viable systems to monitor patient radiation dose in radiography, fluoroscopy, computed tomography and Nuclear Medicine --- Automatic Brightness Control (ABC), Dose-Area Product (DAP Meter), Medical Internal Radiation Dose (MIRD), etc.

(3) More recently, clinically viable radiation dose monitoring and tracking systems (RDMTS), particularly for X-radiation, have been developed, manufactured and marketed for some years not only to ensure better patient care by monitoring and tracking the radiation received by patients but also in response to (a) the public demands and (b) regulatory requirements.
Before Setting Up Enterprise Wide Patient Radiation Dose Monitoring And Tracking Programs.

Let us look at the effort that have been in place for the past decades in trying to reduce patient exposure to Radiation.

(in the previous slide, I have said)

----- “the radiology community as a whole including industry and government agencies, has been actively involved in trying to develop viable systems to monitor patient radiation dose”-----.
Major Approaches **To Reduce** Patients and Personnel **Radiation Dose**

(A) From Equipment Side
1. “Out-of-box” Factory Preprogrammed Examinations
2. “Power ON” Reset of Defaults.

(B) Practice & Operation
1. Examine & Fine Tune Factory Preset, or Preprogrammed Examination Programs
2. Familiarity with the Equipment Operation. (AAPM TG 124 Report)

(C) Global Monitoring and Tracking of Patient Radiation Dose

(D) Dynamic Monitoring and Tracking of Personnel Radiation Dose

71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
A Guide for Establishing a Credentialing and Privileging Program for Users of Fluoroscopic Equipment in Healthcare Organizations

Report of AAPM Task Group 124
AAPM Education Council
Medical Physics Education of Physicians Committee
December 2012

DISCLAIMER: This publication is based on sources and information believed to be reliable, but the AAPM, the authors, and the editors disclaim any warranty or liability based on or relating to the contents of this publication.

The AAPM does not endorse any products, manufacturers, or suppliers. Nothing in this publication should be interpreted as implying such endorsement.

© 2012 by American Association of Physicists in Medicine

Task Group 124 Members

Mary E. Moore (Chair)
Benjamin R. Archer
Stephen Blatter
Joel F. Gray
Alma N. Jackson
Rosemary Kennedy
Pen-Pan Liu
Melissa C. Martin
Edward L. Nickhold
Phillip L. Rauch
Mark S. Rzoncaiski
Douglas Shaefer
Keith J. Stassen
Louis K. Wagner
Lynne Fairbont, AAPM Staff

Approvals:
Task Group 124 Members – June 28, 2012
Medical Physics Education of Physicians Committee – July 13, 2012
AAPM Education Council – October 18, 2012

Consultants:
The Task Group wishes to express its appreciation for the assistance provided by the following consultants:

Libby F. Bartenhagen, Karen L. Brown, Priscilla F. Butler,
Charles E. Chambers, and Gerald A. White

1. This is mainly determined by the equipment selected/purchased.
   a. To change most of the settings may require service engineers to work on the modification.
   b. Certain parameters may not be modified as it is controlled under basic engineering specifications.

2. Manufacturers have spent much of their resources in their Research & Development Division in “Reducing the Patient Dose while trying to maintain the image quality”.

3. The Operation Logic of Automatic Dose Rate and Image Quality Control Programs (ADRIQC) can be evaluated by the end users for further modifications, if necessary. (AAPM TG 125 Report.)
The mechanical design has been perfected over past few decades and has evolved to “specialized” mechanical design and configurations, from the equipment shown in this picture to the special procedures suites shown in the next slide.
Notice the Placement of X-ray Tube in Lateral Plane.

Trade offs between “Access” to the patient and “Scattered Radiation”. There are reasons to “why” the configuration of the lateral plane may results in two different projections in the mechanical design of Positioners. All equipment manufacturers have the mechanical system configuration in both orientations. It depends on, for example, the physical size of the image receptor and for what examinations the imaging system will be employed. [In 2013 RSNA, Toshiba Medical Systems announced a system that can be flipped/rotated to either configuration.]
1. Digitization of Acquired Image and/or Direct Digitization of Image acquisition.
   a) Image Intensifier with Analog-to-Digital Convertor. (Hybrid System)
   b) Application of Flat Panel Image Receptor (Direct Digital System)

2. Implementation of Spectral Shaping Filters in the Automatic Brightness Control (ABC), or Automatic Dose Rate and Image Quality Control (ADRIQC) Program, AAPM Report TG 125;
   a) Traditional Method (ABC).
   b) Anatomical Program Based Filter Selection Method. (Static Filter Selection.)
   c) Seissl Method. (Dynamic Filter Selection.)
AAPM REPORT NO. 125

Functionality and Operation of Fluoroscopic Automatic Brightness Control/Automatic Dose Rate Control Logic in Modern Cardiovascular and Interventional Angiography Systems

A Report of AAPM Task Group 125 Radiography/Fluoroscopy Subcommittee, Imaging Physics Committee, Science Council

June 2012

DISCLAIMER. This publication is based on sources and information believed to be reliable, but the AAPM, the authors, and the editors disclaim any warranty or liability based on or relating to the contents of this publication.

The AAPM does not endorse any products, manufacturers, or suppliers. Nothing in this publication should be interpreted as implying such endorsement.

© 2012 by American Association of Physicists in Medicine

Task Group 125

Co-Chairmen
Pui-Jan Paul Lin
Beth Israel Deaconess Medical Center, Boston MA 02115

Philip Rauch
Henry Ford Health System, Detroit, MI 48202

Task Group Members
Stephen Baker
Columbia University Medical Center, New York, NY 10012

Atsushi Fukada
Shiga Medical Center for Children, Moriyama City, Shiga-Ken, Japan 524-0022

Alien Good
University of Virginia Health Science Center, Charlottesville, VA 22908

Gary Hartwell
University of Virginia Health Science Center, Charlottesville, VA 22908

Terry Lafiance
Baystate Health Systems, Inc., Springfield, MA 01199

Edward Nickleff
Columbia University Medical Center, New York, NY 10032

Jeff Shepard
University of Texas M.D. Anderson Cancer Center, Houston, TX 77030

Keith Strauss
Cincinnati Children's Hospital Medical Center, Cincinnati, OH 45229

iii
Spectral Shaping Filters and The Operation Logic of Automatic Brightness Control for Fluoroscopy Operation and Acquisition Mode. [Or, Fluoroscopy Operation Logic Design (FOLD)]

- The value of spectral filters made of Aluminum (Al, Z=13) and Copper (Cu, Z=29) in the reduction of patient dose was recognized since early 1950s.
- Various elements have been investigated, among others, such as:
  - Niobium (Z=41)
  - Tin (Z=50)
  - Tantalum (Z=73)
  - Gold (Z=79)
- However, Copper (Cu, Z=29) has been employed as the primary “Spectral Shaping Filter”. Typically, the thickness of copper used is in the range of 0.1~0.9 mmCu.

- There are basically two (or three) different schools of how the spectral beam filtration in fluoroscopy is implemented.
  - Traditional Method; where the filters are fixed in the collimator and remain in the primary beam at all time.
  - Program-Switched Method
    1) Anatomical Program Based Filter Selection; this is an advanced version of the radiation method in which the filter is selected based on the “Examination”, and the “Mode” of operation selected by the operator.
    2) Seissl Method; the filters are dynamically selected under a predetermined scheme.

In order to evaluate the Operation Logic of Fluoroscopy; a.k.a., Fluoroscopy Curve (or, Trajectories).
- Refer to AAPM TG 125 Report.
- Typical Geometry is shown on the right.
- Vary the PMMA Phantom Thickness
- Record the following information:
  - Tube Potential (kVp)
  - Tube Current (mA)
  - Pulse Width (msec)
  - Spectral Filter Selection (mmCu)
  - Patient Air Kerma (mGy/min)
  - Image Receptor Air Kerma (μGy/sec)


71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
Data obtained from A Siemens AXIOM Artis dBA Angiography System [Seissl Method]


71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
Data obtained from A General Electric  Precision 500D R&F System [Seissl Method]

Notice that the Spectral Shaping Filter Thickness is increased for PMMA thickness ~10” PMMA when the Tube Potential reached 120 kVp and the Tube Current (not shown) is adjusted to maintain 88 mGy/min output limitation.

Fig. 2. Fluoroscopic tube potential and spectral filter vs PMMA phantom thickness, 9 in. mode.

Fig. 4. Fluoroscopic tube potential and spectral filter vs PMMA phantom thickness, 12 in. mode.

Data obtained from a General Electric Precision 500D R&F System [Seissl Method]
Comparing the application of Spectral Shaping Filters between the Fluoroscopy Mode vs. Acquisition (Digital Spot) Mode.


71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
Anatomical Program Based Filter Selection: The Spectral Shaping Filter is “FIXED” once the user selects the specific examination mode.

Philips Allura Xper 0.1 mmCu + 1.0 mmAl

Shimazu BRANSIST 0.01 mmAu + 1.0 mmAl


71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
Practice and Operation

1. Spend time to setup the Initial Examination Sets with the applications specialist. Modify factory preset programs if necessary.
2. Consult with your Physicist with respect to the Preprogrammed Fluoroscopy Mode and Acquisition Mode Operation Logic; a.k.a. “Automatic Brightness Control”, “Fluoroscopy Curve or Trajectory” on
   a. Initial kVp,
   b. Evaluate Selection of Spectral Filter Thickness to match the examination
   c. Pay special attention to Pediatric vs. Adult Programming,
3. Determine the Dynamic Range of the most often employed Examination between the “Out-of-box Factory Setup” and “Post Fine Tuning”.
4. The final image quality depends on the Operation Logic selected and the adjustment of the “Image Receptor Input Dose”.

71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
Preset Default Values (Fluoroscopy Mode):

- Power “on” Examination selection; Most Often Performed Examination and/or Last Performed Examination?
- Fluoroscopic Frame Rate: 15 f/s or Less (Examination Dependent)
- Fluoroscopic Output Level: “Low” Output Mode?
- Initial Field-Of-View: Depends on the selected examination?

Preset Default Values (Acquisition Mode):

- Acquisition Mode Frame Rate: 15 f/s?
- Aligned with Fluoroscopic Frame Rate? Stepping Mode?
  - a. Cardiovascular Imaging
  - b. Visceral Angiography, Neuroradiological Imaging
  - c. Other Types of Examination; Urology, Pain Clinic, Upper/Lower GI Studies
"Fine Tune" may mean different "Tasks" to different people depending on what needs to be "evaluated" and/or "adjusted".

Start with the Operator Manual where an wealth of information is available.
80kV10RAF2kW Fluoroscopy Curve.
- Initial Starting Point @ 80 kVp.
- Maximum Patient Dose Limit: 10 R/min (88 mGy/min)
- Automatic Focal Spot Control
- 2kW Power Loading

Image Receptor Input Dose.
36 nGy/pulse (Or, 0.54 µGy/s)

Antiscatter Grid Ratio “r”, r=15:1
For Pediatric Case use air gap or “r” less than 8:1?

<table>
<thead>
<tr>
<th>Field-of-View</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>(FOV)“measured diagonally” in cm</td>
<td>48 (rectangular), 42, 32, 22, 16, and 11 (square)</td>
</tr>
<tr>
<td>Focal Spot Size mm</td>
<td>0.6 (default)</td>
</tr>
<tr>
<td>Micro focus: 0.3, small: 0.6, large: 1.2</td>
<td></td>
</tr>
<tr>
<td>Pulse rate (pps: pulses per second)</td>
<td>15 pps (default)</td>
</tr>
<tr>
<td>0.5, 1, 2, 3, 4, 6, 7.5, 10, 15, 30</td>
<td></td>
</tr>
<tr>
<td>80kV10RAF2kW (default)</td>
<td></td>
</tr>
<tr>
<td>24 curves are available/stored on this system</td>
<td></td>
</tr>
<tr>
<td>Detector dose setting (this is flat panel input air kerma rate)</td>
<td>36 nGy/pulse or 0.54 µGy/s (default)</td>
</tr>
<tr>
<td>Fluoroscopy Level Control (this is patient air kerma rate)</td>
<td></td>
</tr>
<tr>
<td>Antiscatter grid, line direction is angled 15°</td>
<td></td>
</tr>
<tr>
<td>Focal length, f_p=105 cm</td>
<td></td>
</tr>
<tr>
<td>Grid ratio, r=15:1</td>
<td></td>
</tr>
<tr>
<td>Line density, N=80 lines/inch</td>
<td></td>
</tr>
</tbody>
</table>


71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
## B) Practice and Operation: Familiarity with the Equipment Operation


2. **User Knowledge of Basic Radiation Physics and Protection**
   a. Place the image receptor to the patient as close as possible,
   b. Use Low Pulse Rate,
   c. Dose vs. Distance, Dose vs. Field-of-View, etc.

3. **Hands-on Equipment Operation In-service may be required**
   a. Understand various International Icons/Symbols
   b. Gantry orientation/control, etc.
Hands-on Equipment Operation In-service may be required.

Control consoles

Omega Smart Box: Items 1, 2, 3 and 4

Omega Table Side Status Control (TSSS)

71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
Caution!

1) The DAP-meter values ARE NOT true patient skin exposure.
2) The DAP-meter “Air Kerma” is calibrated at “Reference Point” that differs from Patient’s Skin Location.
3) The location is dependent of the Fluoroscopy Unit, 
   a) Interventional System 
   b) Conventional R/F Table 
   c) Mobile C-arm 
   d) Over-head Tube R/F Table 
4) The DAP-meter accuracy depends on two factors. 
   a) Accuracy of the Dosimeter 
   b) Accuracy of Field Size Measurement 
A demonstration of **Estimating** the fluoroscopic patient radiation dose.

(1) Let assume; A Radiation Dose was reported on the Single Plane Angiography Equipment via the DAP Meter Reading: **16500 mGy**.

(2) According to The Joint Commission (TJC), this is a “Sentinel Event” and must be reported. (>15 Gy, >15000 mGy)

(3) NOTE: The dose reported is estimated and calibrated at the Reference Point (RP) which, in this case, is defined as 15 cm from the iso-center towards the radiation source along the primary central axis.

**Question (1): Is this a reportable “Sentinel Event”?**

**Question (2): Just how accurate is the DAP-Meter?**

The answer to Question (2) would have to refer to AAPM TG 190 Report.
AAPM TG 190 was established to **Evaluate the Accuracy** of the DAP-meters, and to provide guidance in how the information may be utilized to estimate Patient Exposure to Radiation.

AAPM TG 190 Data Collection gathering at Beth Israel Deaconess Medical Center, BOSTON (with Visitors from Japan).
A demonstration of **Estimating** the fluoroscopic patient radiation dose.

By taking the face-value of the DAP-Meter reading, there are **at least two modification factors** that need to be considered:

(a) The geometry --- is patient’s radiation entrance point near the Reference Point?
(b) The attenuation --- In the case of PA projection, was radiation beam always traversing the Table-and-Mattress?

**Corrective Modifiers** for a better accuracy of **DOSE estimation**:

(a) The geometry --- Often the geometric modification factor is close to “0.8 ~ 1.2” but needs to be evaluated case by case. (Table height information, SID etc. need be known.)
(b) The attenuation --- the tabletop (~1.0 mmAl HVL) and the mattress (~1.0 mmAl HVL) together reduce the radiation intensity by some 30%.
A demonstration of **Estimating** the fluoroscopic patient radiation dose.

The DAP (air kerma dose area product) Meter Reading, **16500 mGy** can be modified downward by multiplying “0.7” to **11550 mGy**.

However, **11550 mGy** is still above the Institutional Reportable Level of 8500 mGy which is a preset value mandated by our institution to track the patient’s “potential skin injury”.

The patient is evaluated by a Radiation Oncologist, who are more familiar with the radiation induced skin injury than most other physician, in a predetermined interval post the interventional procedure in the event additional patient care is necessary.
Global Monitoring and Tracking of Radiation Dose

As demonstrated, the fluoroscopic patient dose may be monitored and estimated. However, the total radiation dose received by any given patient while cared for in the Hospital may be **accrued from multiple number of radiological imaging events**.

The radiation received by a patient needs to be monitored and tracked while hospitalized.

A patient may be **returned multiple times** who lives and work in the same community.

While the deterministic radiation injury is the primary concern, the stochastic radiation effect should also be evaluated when a long term tracking of radiation dose is available.
(C) Global Monitoring and Tracking of Radiation Dose

- Required by The Joint Commission (TJC)
- Required by State Law
- Fluoroscopy “ON” time alone is not an adequate parameter and is no longer considered sufficient for patient dose monitoring due to its large range and inaccuracy.
- Individualized recording of fluoroscopy dose including every examination (Fluoroscopy, Radiography, CT, Nuclear Medicine Studies) performed on the patient.
- There is no straight forward solution (like automatic data entry to the Monitoring-and-Tracking software programs) to include the dosimetry of Nuclear Medicine due to its vastly different way to obtain the patient dose from the X-ray Dosimetry.
- Dose Area Product (DAP-meter) Readings; by a physical DAP-meter or by calculation. (Accuracy, DAP Reading to Actual Patient Dose Conversion Factor ---- AAPM TG 190)
- CT examination present a different problems from the Fluoroscopy and Radiography examination.

71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN , [E-mail address: pjlin@vcu.edu]
(C) Global Monitoring and Tracking of Radiation Dose

The priority of dose monitoring is in the areas where Potentially High Dose Examination is conducted routinely, such as;

a. Cardiovascular Interventional Studies which include “Angiography and Interventional Angiography” in
   1. Cardiac Catheterization Laboratories,
   2. Electro Physiology Laboratories,
   3. Interventional Radiology Suites.
   4. And, even the Pain Clinic

b. CT Examinations where “repetitive” exposure of same anatomical region is required, such as;
   1. Perfusion Studies of CT
   2. Cardiac Angiography of CT
There are several software products that handle “Global” monitoring and tracking of patient radiation dose.

Dosimetry information may be acquired through:
1. Hardwire Connection
2. DAP Meter Reading
3. Modality Performed Procedure Step (MPPS)
4. Radiation Dose Structured Report (RDSR)
1) Radiation Dose Structured Report (RDSR) is optimized for fluoroscopically guided procedures and its main focus is on “management” of radiation dose delivered to the patient. It was released as part of the 2007 DICOM Standards.

2) The RDSR records all “exposures” made during the procedure irrespective of whether the images were deleted post examination. The RDSR had been required to be conformant with IEC 60601-2-043.

3) RDSR is designed such that the contents can be exported to the PACS and captured by “Dose Management” free-standing software programs.

4) The “PEMNET” from Clinical Microdevices Inc., “eXposure” from Bayer HealthCare, “DoseWatch” from GE Healthcare are examples of such dose management programs.
PEMNET Report Builder Console

View Patient IR, Cardiac, & CT Procedural History from ANY Workstation

71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
Explore the effect of scan length on dose to the patient

Reproduced with permission from slide presentation of “eXposure”. Bayer HealthCare. (Radimetrics)

71st Annual Scientific Congress of Japanese Society of Radiological Technology, Yokohama, JAPAN, [E-mail address: pjlin@vcu.edu]
(C) Global Monitoring and Tracking of Radiation Dose

Other Interface/connections that need to be considered within a given radiological examination:

(I) “Contrast Medium” Dose Information. ---- The contrast media power injector virtual server.
   1) From CT Scanners.
   2) From Interventional cardiovascular procedures.
   3) From Upper/Lower GI Studies.

(II) “Anesthesia Drug Dose”. ---- Interface with anesthesia data recording system?

(III) Export data to: Requirement of “Patient Dose”, both radiation and contrast medium, Information be recorded on the Medical Report which means;
   1) Interface with radiology dictation machine.
   2) Interface with Patient Examination Report System.
   3) Integration with Medical Record.
(C) Global Monitoring and Tracking of Radiation Dose

So, we took care of patients!
Need Detailed Mapping of Radiation Dose Delivered to the patient’s skin surfaces:
Developed by
Siemens: CareGraph
GE: DoseMap
Toshiba: XXXXX
Philips: DoseWise

• Personnel Dose Monitoring;
• Personal Dose Meter;
• Badges --- Delays!
• Need immediate feed back of Dose received!
• Philips: DoseAware
• Landauer: Verifii Digital Dosimetry Platform.
There may be a need to monitor “personnel” exposure for individuals who work in “high radiation dose environment” such as Cardiovascular Interventional Angiography.

Products similar to DoseAware may be of great help to reduce personnel dose and become aware of the exact “situation” when and where the “high” radiation dose is received.

Reproduced with permission from Philips Healthcare.

May also be accessed via http://www.newscenter.philips.com/jp_ja/standard/about/news/healthcare/121023_doseaware.wpd#.VQdMt47F-Ck
Thank you very much for your kind attentions and attending this session!

To receive the presentation later, please e-mail me at <pjlin@vcu.edu>,

Or, Copy the URL below onto your favourite WEB Browser & Click on: