Establishing a patient safety program in Interventional Radiology

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Disclosure

- I am co-owner of Fluoroscopic Safety, LLC, a company that provides training for physicians in the safe use of fluoroscopy.
- Fluoroscopic Safety is not discussed in this presentation.
Why?

• We are practicing in an era of increased emphasis on quality and patient safety
• Reimbursement models are changing with emphasis on outcomes and minimizing/managing complications
• Ethical considerations
• Accreditation and regulatory considerations
Updates to TAC 289.227

• Requires creation of a Fluoroscopy Radiation Protocol Committee
  – RSC for fluoroscopy

• Required tasks
  – Meet
  – Restrict use of fluoroscopy
    • Radiologist, R.O., or physician completing 8 hrs Cat. 1 CME + 1 hr hands on training
    • aka privileges
  – Record dose descriptors
  – Establish reference levels and review process
RISKS OF FLUOROSCOPICALLY GUIDED PROCEDURES
Who is at risk?

- Physicians
- Nurses
- Technologists
- Anesthesiologists
- Patients
- Facilities
Risks to the operator and staff

- Infection
- Back injury
- Falls
- Heavy objects
- Litigation
- Radiation-induced cataracts
- Radiation-induced cancer
Risks to the patient

- Death
- Puncture of vessel
- Contrast reaction
- Hematoma
- Infection
- Stochastic effects from radiation exposure
- Tissue effects from radiation exposure
Stochastic effects

• Stochastic effect – risk ↑ linearly with dose
• Risk depends on
  1. Volume of tissue irradiated
  2. Type of tissue irradiated
  3. Total dose delivered to tissue
  4. Age of patient
  5. Patient genetics
• There is always a risk of stochastic effects if we use ionizing radiation, but these risks can be managed
Stochastic effects

• In some cases the risk to the patient can be reduced
• Procedural planning and situational awareness are key

Tissue effects

• Tissue effects have a threshold
  – Risk = 0 below a certain dose*
  – Severity increases with increasing dose above threshold dose

• Our understanding of tissue effects has been evolving

• In most cases, can be prevented
  – Training of operators
  – Safety program
  – QC of equipment
Threshold doses for tissue effects

• For many years, hard thresholds for various types of tissue effects were quoted

• It has become apparent that these “thresholds” can vary widely between patients

• Depends on
  1. Patient genetics
  2. Prior skin irradiation
  3. Disease state/treatment
### Table 1

**Tissue Reactions from Single-Delivery Radiation Dose to Skin of the Neck, Torso, Pelvis, Buttocks, or Arms**

<table>
<thead>
<tr>
<th>Band</th>
<th>Single-Site Acute Skin-Dose Range (Gy)*</th>
<th>NCI Skin Reaction</th>
<th>Approximate Time of Onset of Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prompt</td>
</tr>
<tr>
<td>A1</td>
<td>0–2</td>
<td>NA</td>
<td>No observable effects expected</td>
</tr>
<tr>
<td>A2</td>
<td>2–5</td>
<td>1</td>
<td>Transient erythema</td>
</tr>
<tr>
<td>B</td>
<td>5–10</td>
<td>1–2</td>
<td>Transient erythema</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>10–15</td>
<td>2–3</td>
<td>Transient erythema</td>
</tr>
<tr>
<td>D</td>
<td>&gt;15</td>
<td>3–4</td>
<td>Transient erythema; after very high doses, edema and acute ulceration; long-term surgical intervention likely to be required</td>
</tr>
</tbody>
</table>

Note.—Applicable to normal range of patient radiosensitivities in absence of mitigating or aggravating physical or clinical factors. Data do not apply to the skin of the scalp. Dose and time bands are not rigid boundaries. Signs and symptoms are expected to appear earlier as skin dose increases. Prompt is <2 weeks; early, 2–8 weeks; midterm, 6–52 weeks; long term, >40 weeks.

* Skin dose refers to actual skin dose (excluding backscatter). This quantity is not the reference point air kerma described by Food and Drug Administration (21 CFR § 1020.32 [2006]) or International Electrotechnical Commission (57). Skin dosimetry is unlikely to be more accurate than ± 50%. NA = not applicable.

1 NCI = National Cancer Institute
2 Refers to radiation-induced telangiectasia. Telangiectasia associated with area of initial moist desquamation or healing of ulceration may be present earlier.

Radiation injuries

- Radiation-induced skin injuries are particularly troublesome for several reasons
  - Patient does not experience any sensations
  - Latent period means that cause and effect may not be connected by patient or physician
Multiple coronary angiography, angioplasty, and bypass graft on a single day – estimated peak skin dose > 20 Gy

6-8 weeks post procedure
16-21 weeks post procedure
18-21 months post procedure

Shope TB. Radiation-induced skin injuries from fluoroscopy.

A. Kyle Jones, Ph.D. AAPM 2013 WE-A-144-1
Radiation injuries

- Radiation injuries can be particularly gruesome and, depending on severity, may never completely heal.

Wagner LK, Archer BR. Minimizing Risks from Fluoroscopic X Rays: Bioeffects, Instrumentation, and Examination, 3rd edition; Houston, TX: R. M. Partnership, 2000

What can we do?

- **Reduce** the risk of stochastic effects for operator, staff, and patient
- **Prevent** most tissue effects such as radiation-induced cataracts and skin injuries
- **Recognize** situations where a high probability for injury exists so the patient can be appropriately medically managed
Three-pronged approach

• Pre-procedure actions
• Intra-procedure actions
• Post-procedure actions
Quality Initiatives

Establishing an Interventional Radiology Patient Radiation Safety Program

Joseph R. Steele, MD • A. Kyle Jones, PhD • Elizabeth P. Nixan, PA-C

The Interventional Radiology Patient Radiation Safety Program was created to better educate patients who are scheduled to undergo high-dose interventional radiologic procedures about the risks of radiation, better monitor the delivered doses, and reduce the risk for deterministic effects. The program combines preprocedure evaluation and counseling, intraprocedure monitoring, and postprocedure documentation and counseling with the guidelines of the National Cancer Institute and the Society of Interventional Radiology. Between July 2009, when the program was implemented, and September 2010, over 3500 interventional radiologic procedures were monitored and documented, and 63 procedures with an adjusted cumulative dose of more than 3 Gy were identified and further analyzed; four procedures were found to be outside the control limits. Additional review of these four procedures resulted in practice modifications. Anecdotal feedback from physician assistants and attending physicians indicated that the program had another positive effect: Patients who required postprocedure counseling about the potential for radiation-induced skin injuries were no longer surprised by this information. Implementation of this program is straightforward, requires little infrastructure and few resources, and may be applied in most interventional radiology practices. Supplemental material available at http://radiographics.rsna.orglookup/suppl/doi:10.1148/rg.321115092/-/DC1.

Abbreviations: CD = cumulative dose; CD₃₀ = adjusted cumulative dose; DAP = dose-area product; RAD-IR = Radiation Doses in Interventional Radiology Procedures

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PRE-PROCEDURE ELEMENTS
Informed consent

“Informed consent is a patient's right to be presented with sufficient information, by either the physician or their representative, to allow the patient to make an informed decision regarding whether or not to consent to a treatment or procedure.”

http://www.med-ed.virginia.edu/courses/rad/consent/
Informed consent

“Informed consent is a patient's right to be presented with sufficient information, by either the physician or their representative, to allow the patient to make an informed decision regarding whether or not to consent to a treatment or procedure.”

http://www.med-ed.virginia.edu/courses/rad/consent/
I (we) also realize that the following risks and hazards may occur in connection with this particular procedure: *Specific Information Here*

- Arteriography
- Venography
- Interventional

1. Injury to artery or vein
2. Loss of function or damage to parts of the body supplied by the artery or vein
3. Swelling, pain, tenderness or bleeding at site of blood vessel perforation
4. Aggravation of the condition that necessitated the procedure
5. Allergic reaction to injected contrast media
6. Possible kidney damage from injected contrast media
7. 

   Just as there may be risk and hazards in continuing my present condition without treatment, there are also risks and hazards related to the performance of the surgical, medical, and/or diagnostic procedures planned for me.

   I (we) realize that common to surgical, medical, and/or diagnostic procedures, is the potential for infection, blood clots in veins and lungs, hemorrhage, pain, emergent coronary bypass surgery, myocardial infarction, arrhythmia’s, renal failure, stroke, allergic reactions, and even death.
Informed consent

• Lack of informed consent is grounds for malpractice lawsuit

• Ethical considerations

---

I (we) also realize that the following risks and hazards may occur in connection with this particular procedure: **Specific Information Here**

- [ ] ARTERIOGRAPHY/ [ ] VENOGRAPHY
  1. Injury to artery or vein.
  2. Loss of function or damage to parts of the body supplied by the artery or vein.
  3. Swelling, pain, tenderness, or bleeding at site of blood vessel perforation.
  4. Aggravation of the condition that necessitated the procedure.
  5. Allergic reaction to injected contrast media.
  6. Possible kidney damage from injected contrast media.

- [ ] INTERVENTIONAL
  - [ ] Pain
  - [ ] Bleeding
  - [ ] Infection
  - [ ] Damage to Surrounding Structures
  - [ ] Pneumothorax (Collapsed Lung)
  - [ ] Hemoptysis (Coughing Up Blood)
  - [ ] Risk of radiation-induced skin injury; In rare cases of lengthy or complex procedures utilizing x-ray, radiation-induced skin injuries have been reported (<1% of cases)

- [ ] Off-Label Use
Patient education

• PA/physician must have the tools and knowledge to simply explain the risks to the patient without inducing panic
• One approach to this is a pamphlet/handout
  – Mechanisms of injury
  – How we prevent injuries
  – Decisions made during the case
Identify high-risk patients

- Certain conditions are suspected to pre-dispose patients to radiation induced skin injuries
  - Diabetes mellitus
  - Connective tissue disorders
  - Ataxia telangiectasia
  - Drug interactions

- Also, a recent high dose procedure can result in the induction of effects at lower doses in the future


Identify high-risk patients

• Most easily done during the consenting process
• The RIS can be used to automatically identify and flag these patients
• High-risk patients can be routed to a dose sparing protocol, physician can be advised
  – Fewer acquisition runs, more storing of fluoro
  – Alternate $K_{a,r}$ thresholds
  – Postpone procedure?
Multiple and repeated procedures

- Two scenarios
  1. By performing a very complex case in multiple sessions, fx can be used to reduce late effects
  2. If a procedure is repeated, an unexpected skin reaction may occur as the Biologically Equivalent Dose from the two procedures is greater than the dose from either individual procedure
- We can look to radiobiology for guidance on managing multiple irradiations of the skin

Training of physicians and staff

• Physicians performing fluoroscopically-guided procedures should be trained in the safe use of fluoroscopic equipment
  – NCRP 168
  – State regulations
• Continuing education
• Understand dose saving features of each type of equipment on which they work
  – Hands-on component

**Recommendation 28**

An FGI procedure *shall* be performed or supervised only by a physician or other medical professional with fluoroscopic and clinical privileges appropriate to the specific procedure.

NCRP 168
Training resources

http://www.aapm.org/education/ERG/
Privileging of physicians and staff

• *Credentials* relate to training, education, and experience
  – Medical degree/residency/fellowship
  – Board certification

• *Privileges* delineate which medical procedures a staff member may perform
  – Specific to institutions/departments
Privileging of physicians and staff

- AAPM Task Group 124 has published their report:

  A Guide for Establishing a Credentialing and Privileging Program for Users of Fluoroscopic Equipment in Healthcare Organizations

which is the definitive resource
INTRA-PROCEDURE ELEMENTS
Recommendation 14

Interventionalists *shall* be responsible for patient radiation levels during FGI procedures and *shall* ensure that radiation dose accumulation is continuously monitored during the procedure.
Reference air kerma (K_{a,r}) thresholds

• All equipment manufactured after June 2006 is required by law to display the K_{a,r}
• Alerting the physician at certain points guarantees there are no surprises at the end of a case
• Decisions can be made based on medical management at each threshold
  – Pace of procedure
  – Good practice (YDNKWIHUYKWIH)
Establishing $K_{a,r}$ thresholds
Table 4.7—Suggested values for first and subsequent notifications and the SRDL.

<table>
<thead>
<tr>
<th>Dose Metric</th>
<th>First Notification</th>
<th>Subsequent Notifications (increments)</th>
<th>SRDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{\text{skin,max}}$</td>
<td>2 Gy</td>
<td>0.5 Gy</td>
<td>3 Gy</td>
</tr>
<tr>
<td>$K_{a,r}$</td>
<td>3 Gy</td>
<td>1 Gy</td>
<td>5 Gy(^a)</td>
</tr>
<tr>
<td>$P_{KA}$</td>
<td>300 Gy cm(^2)(^b)</td>
<td>100 Gy cm(^2)(^b)</td>
<td>500 Gy cm(^2)(^b)</td>
</tr>
<tr>
<td>Fluoroscopy time</td>
<td>30 min</td>
<td>15 min</td>
<td>60 min</td>
</tr>
</tbody>
</table>

\(^a\)See additional discussion concerning the value 5 Gy in Section 4.3.4.2.

\(^b\)Assuming a 100 cm\(^2\) field at the patient’s skin. For other field sizes, the $P_{KA}$ values should be adjusted proportionally to the actual procedural field size (e.g., for a field size of 50 cm\(^2\), the SRDL value for $P_{KA}$ would be 250 Gy cm\(^2\)).
Setting notification levels

• Use a representative phantom and perform a “procedure” on the phantom
  – Measure ESD (cannot used lead-backed dosimeter)
  – Correct geometry
  – Distribution of acquisition/fluoroscopy
• Apply f-factor, use ratio of $K_{a,r}/PSD$ to determine notification levels
  – VIR ~ 1
  – Cardiology ~ 0.7-0.8
  – Neuro ~ 0.8-1.0
• Some manufacturers allow a number of notification levels to be programmed in the system
A very important piece of information

• Estimating the PSD with any degree of accuracy REQUIRES knowledge of the source-to-patient distance (SPD)
• If this information is not available in DICOM headers or the RDSR, it must be recorded manually
• Provide instructions to the technologist or other staff for measuring and recording the SPD when the SRDL is reached
Situational awareness

- For patients who have undergone a recent high dose procedure, use a different projection to reduce the cumulative skin dose
  - Reduce 95% area load
  - May not reduce PSD

- May not be able to completely eliminate overlap, but for angled projections can have large benefit
  - Importance of tight collimation
LABORATORY INVESTIGATION

Does “Spreading” Skin Dose by Rotating the C-arm during an Intervention Work?
Alexander S. Pasciak, PhD, and A. Kyle Jones, PhD

ABSTRACT

PURPOSE: To determine if C-arm rotation is beneficial for reducing peak skin dose (PSD) in interventional radiology (IR) and, if so, under what circumstances.

MATERIALS AND METHODS: The Monte Carlo method was used to perform ray tracing for detailed analysis of the effect of C-arm rotation on PSD across a range of patient sizes, C-arm configurations, and procedure types. Automatic dose-rate control curves on modern fluoroscopic systems were measured for input into the simulations.

RESULTS: Rotating the C-arm to reduce the PSD is in most cases contraindicated and results in increased PSD when the C-arm is rotated from an original posterioranterior projection, in some cases resulting in a PSD increase by a factor of 5 or more. When prophylactic rotation was performed before a procedure, however, and the C-arm was rotated between opposed, distinct oblique angles, substantial reduction in PSD was achieved for patients of any size.

CONCLUSIONS: Rotating the C-arm during a procedure with the aim of “spreading” dose on the skin of the patient may not result in a reduction in PSD and may increase PSD. However, when used as a prophylactic measure combined with tight C-arm collimation, C-arm rotation can be used as a tool to reduce PSD. Tight collimation greatly increases the benefit of C-arm rotation.

ABBREVIATIONS

ADRC = automatic dose rate control, Kx = reference point air kerma, LAO = left anterior oblique, PSD = peak skin dose, RAO = right anterior oblique, SSD = source-to-aim distance

Fluoroscopically guided interventional procedures, which are minimally invasive and have fast recovery times, have become the preferred treatment for many conditions that previously required open surgical intervention. In addition, modern fluoroscopic imaging systems and in particular adjuncts such as three-dimensional rotational angiography, have increased the scope of interventional radiology (IR) procedures (1–5). As the scope of fluoroscopically guided IR has increased, so has the complexity of the procedure, sometimes necessitating extensive use of ionizing radiation or repeated applications, which may put the patient at risk for deterministic skin injury (6,7). Radiation-induced skin injuries are a rare but potentially debilitating side effect of lengthy IR procedures (7–11).

Methods for reducing peak skin dose (PSD) (this term and others that appear in this article are defined in Table I) have been addressed extensively (6,12–17). One technique that has often been recommended is rotation of the C-arm at various times during a procedure (6,12,14–16). Although one such recommendation is specific to interventional cardiology (12), most authors make general recommendations. This practice is common and is often taught to radiology residents and fellows during clinical training and in commercially available credentialing programs (13). The technique is often applied in a cursory fashion, with little knowledge of how the rotation actually affects the PSD, especially for different patient and x-ray field sizes. Also, timing of C-arm rotation, doses, angles, electronic magnification modes, patient size, and the radiographic magnification factor each impacts the effectiveness of varying the C-arm angle and should be considered individually.

Interventional cardiology and IR procedures are performed with different imaging geometries. Because it is often necessary to rotate the C-arm in interventional cardiology procedures to obtain different projections for diag-
Figure 5. Zero-overlap angle as a function of patient size for rotation from initial posteroanterior projection. (a) Abdominal interventions. (b) Pelvic interventions. Lines show the minimum angle to which the C-arm must be rotated, as a function of patient size, to avoid completely overlap between the x-ray field entrance sites on the patient’s skin. Each different line corresponds to a different x-ray field size or shape or both.
SU-E-I-24

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POST-PROCEDURE ELEMENTS
Record dose descriptors

• Medical record has been suggested
  – Perhaps difficult
  – May not be searchable
    • Dictated
    • Scanned
  – What is and what is not part of the medical record?
• DICOM Structured Dose Reporting is here
  – Recently installed our first system (VC14)
  – Legacy systems may never support
  – Third party options are available
• DICOM headers contain some information
Recommendation 15

Patient dose data shall be recorded in the patient’s medical record at the conclusion of each procedure. This shall include all of the following that are available from the system: $D_{\text{skin, max}}$, $K_{a,r}$, $P_{\text{KA}}$, fluoroscopy time, and number of fluorographic images.
Exam Protocol

Patient Info:

Patient Position: HFS

<table>
<thead>
<tr>
<th>Exam</th>
<th>Voltage</th>
<th>Current</th>
<th>Time</th>
<th>Dose Rate</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DSA</td>
<td>79kV</td>
<td>392mA</td>
<td>100.0ms</td>
<td>16s</td>
<td>4F/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>large</strong></td>
<td><strong>0.1Cu</strong></td>
<td><strong>48cm</strong></td>
<td><strong>4918.3\mu GY\textsuperscript{2}</strong></td>
<td><strong>166mGy</strong></td>
</tr>
<tr>
<td>2</td>
<td>DSA</td>
<td>81kV</td>
<td>331mA</td>
<td>100.0ms</td>
<td>10s</td>
<td>4F/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>large</strong></td>
<td><strong>0.0Cu</strong></td>
<td><strong>32cm</strong></td>
<td><strong>3460.8\mu GY\textsuperscript{2}</strong></td>
<td><strong>213mGy</strong></td>
</tr>
<tr>
<td>3</td>
<td>DSA</td>
<td>82kV</td>
<td>375mA</td>
<td>100.0ms</td>
<td>6s</td>
<td>4F/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>large</strong></td>
<td><strong>0.0Cu</strong></td>
<td><strong>32cm</strong></td>
<td><strong>2114.7\mu GY\textsuperscript{2}</strong></td>
<td><strong>130mGy</strong></td>
</tr>
<tr>
<td>4</td>
<td>DSA</td>
<td>80kV</td>
<td>387mA</td>
<td>100.0ms</td>
<td>12s</td>
<td>4F/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>large</strong></td>
<td><strong>0.0Cu</strong></td>
<td><strong>32cm</strong></td>
<td><strong>4045.3\mu GY\textsuperscript{2}</strong></td>
<td><strong>249mGy</strong></td>
</tr>
<tr>
<td>5</td>
<td>DSA</td>
<td>82kV</td>
<td>376mA</td>
<td>100.0ms</td>
<td>12s</td>
<td>4F/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>large</strong></td>
<td><strong>0.0Cu</strong></td>
<td><strong>32cm</strong></td>
<td><strong>4242.9\mu GY\textsuperscript{2}</strong></td>
<td><strong>261mGy</strong></td>
</tr>
<tr>
<td>6</td>
<td>DSA</td>
<td>80kV</td>
<td>385mA</td>
<td>100.0ms</td>
<td>17s</td>
<td>4F/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>large</strong></td>
<td><strong>0.0Cu</strong></td>
<td><strong>32cm</strong></td>
<td><strong>5841.4\mu GY\textsuperscript{2}</strong></td>
<td><strong>355mGy</strong></td>
</tr>
<tr>
<td>7</td>
<td>DSA</td>
<td>81kV</td>
<td>381mA</td>
<td>100.0ms</td>
<td>14s</td>
<td>4F/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>large</strong></td>
<td><strong>0.0Cu</strong></td>
<td><strong>32cm</strong></td>
<td><strong>4647.8\mu GY\textsuperscript{2}</strong></td>
<td><strong>286mGy</strong></td>
</tr>
<tr>
<td>8</td>
<td>DSA</td>
<td>82kV</td>
<td>375mA</td>
<td>100.0ms</td>
<td>16s</td>
<td>4F/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>large</strong></td>
<td><strong>0.0Cu</strong></td>
<td><strong>32cm</strong></td>
<td><strong>5612.6\mu GY\textsuperscript{2}</strong></td>
<td><strong>345mGy</strong></td>
</tr>
</tbody>
</table>
Exam Protocol

Patient Info:

A 100kV 311mA 100.0ms ***** large 0.0Cu 22cm 2014.2μGy² 357mGy 3RAO 5CRA 53F

***Accumulated exposure data***

<table>
<thead>
<tr>
<th>Phys:</th>
<th>08-Oct-12 08:32:19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fluoro:</td>
<td>42.4min</td>
</tr>
<tr>
<td>Exposures: 25</td>
<td>Total: 86792.3μGy² 8208mGy</td>
</tr>
</tbody>
</table>
DICOM SR
Record dose descriptors

• Other possibilities include RIS or logbooks
  – Would like it to be searchable
    • Tracking
    • Practice improvement
    • Identify/prevent sentinel events

• We went with the RIS
  – Manual entry into designated fields
  – Reports can be generated, already linked with procedure (accession number)
  – Automatic analysis of data/entry into database
Record dose descriptors

• What we record:
  – $K_{a,r}$
  – KAP
  – Number of rotational angiography runs (DynaCT)
  – Fluoroscopy time

• Track repeated or multiple procedures
KAP meter calibration

• FDA (2006)/IEC 60601-2-43 (2010) requirement for accuracy ($K_{a,r}$): +/- 35%
  ➢ IEC 60580 (2000) requires +/- 25% accuracy under specific conditions for KAP
• Take the time to measure a single- or double-point calibration factor for the KAP meter in each of your interventional labs

• NEMA XR-27 – facility to store calibration factor(s) in the RDSR
• AAPM TG 190 standardizing measurement procedures
Table 1. Mean values of response ratio $R \text{ cm}^2(\text{calc})/R \text{ cm}^2(\text{indic})$ observed for a particular Diamentor system for ranges of several of the parameters of irradiation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measured range</th>
<th>No of readings</th>
<th>$\frac{R \text{ cm}^2(\text{calc})}{R \text{ cm}^2(\text{indic})}$ (mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative exposure</td>
<td>1.9–11.3 R</td>
<td>6</td>
<td>1.08 ± 0.02</td>
</tr>
<tr>
<td>Exposure rate</td>
<td>20–800 mA</td>
<td>8</td>
<td>1.05 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>(0.1–3.4 R s$^{-1}$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam area</td>
<td>10 × 10–35 × 35 cm$^2$</td>
<td>8</td>
<td>1.06 ± 0.02</td>
</tr>
<tr>
<td>Radiation quality</td>
<td>50–140 kV</td>
<td>10</td>
<td>1.09–0.02</td>
</tr>
</tbody>
</table>


My experience (1 manufacturer) for $K_{a,r}$ accuracy:

- Generally +/- 15% across all FOV and rates (FLU, ACQ, CINE)
- Generally less accurate as FOV is reduced
- Taking advantage of lenient limits?
Automated solutions

- Clinical Microsystems
- GE DoseWatch
- Siemens CareAnalytics
- Radimetrics
Flagging and follow up

• A case where our substantial radiation dose level (SRDL) is reached is flagged by the technologist, triggering our f/u protocol (PA):
  – Patient informed that SRDL (>= 5 Gy) was reached and why
  – Patient instruction provided (one sheet)
    • Signs/symptoms (red area the size of your hand)
    • Instructions (do not scratch or itch)
    • Actions (call us)
  – Telephone or in-person f/u scheduled for 4 weeks
  – Verify that dose report is archived
**Recommendation 16**

If a substantial radiation dose level (SRDL) (Table 4.7 and Section 4.3.4.2) is exceeded while performing an FGI procedure, the interventionalist *shall* place a note in the medical record, immediately after completing the procedure, that justifies the radiation dose level used.

**Recommendation 17**

If an SRDL is exceeded for an FGI procedure, the patient and any caregivers *should* be informed, prior to discharge, about possible deterministic effects and recommended follow-up.

If fluoroscopy time exceeds the SRDL, but other measured dose metrics do not exceed the SRDL, patient information and follow-up *may not* be necessary.
Medical management of skin reactions

• Acute skin doses greater than a few Gy are only seen in medicine as a result of fluoroscopically guided procedures
• Knowing who to consult regarding skin reactions is tricky
• Dermatologists may never have seen these types of reactions
• Radiation oncologists seem to be the best to discuss these matters with
  — Typically do not see late/acute effects of same severity
Practice improvement

• Dose information collected can be used to calculate dose metrics that can be used to accomplish data driven practice improvement
  – Compare dose metrics to national averages
    • RAD-IR study
  – Identify procedures/physicians/etc. for improvement
  – Control charts for identifying exceptional variation
    • Discuss SRDL/reactions at QI conference or M+M
Recommendation 19

Facilities *shall* have a process to review radiation doses for patients undergoing FGI procedures.

Advisory data based on measured dosimetric quantities (in particular $P_{KA}$ or $K_{a,r}$ to manage overall performance, and $K_{a,r}$ to manage deterministic effects) *should* be used for quality assurance purposes.
Radiation dose audits


A. Kyle Jones, Ph.D. AAPM 2013 WE-A-144-1
Don’t audit only “high dose” cases...

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Hepatic chemoembolization

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Pelvic arterial embolization (tumor)

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# Nephrostomy placement

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In certain circumstances

• It is necessary and appropriate to administer a high dose of radiation during a fluoroscopically guided procedure
• One must still be conscious of how much radiation has been used
• The risk of injury must be commensurate with the benefits of the procedure
• Medical management after the procedure must be appropriate
Acknowledgements

• Lou Wagner, Ph.D.
• Joseph Steele, M.D.
• Alex Pasciak, Ph.D.
Further reading

  - SIR Standards of Practice Committee
  - SIR Safety and Health Committee
  - Discharge/consenting examples
- NCRP Report 168