Radiation Effects from Fluoroscopic X Rays

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1. Radiation Effects from Fluoroscopic X Rays

Radiation Effects Fluoroscopy

What we will do in this presentation (objectives):
1. Review the history of radiation effects in medicine with emphasis on fluoroscopy
2. Review the dose-response effects from fluoroscopic radiation.
3. Develop perspectives regarding our professional responsibilities in light of this information

Established Facts

1. Fluoroscopy has induced cancer in patients
2. Fluoroscopy has seriously injured patients
3. Fluoroscopy has caused cancer in medical staff
4. Fluoroscopy has caused skin injury in medical staff
5. Fluoroscopy has caused cataracts in medical staff
6. Medical staff have died from disease induced by medical fluoroscopy
7. Medical practitioners as a group are not well versed in the risks and exposures to patients from medical radiations

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In patients, effects typically due to accumulation of high radiation doses in a short time period, except for...

...potential hypothetical stochastic effects —

Induced neoplasm
Heritable genetic effects

— which are hypothesized as possible at any dose.

Priority of concerns for fluoroscopy:

1. Short-term (weeks to months) debilitating deterministic effects (e.g., radiation injury)
2. Long-term (years to decades) debilitating deterministic risks (e.g., cataract, osteonecrosis)
3. Long-term stochastic risks (e.g., cancer) [Typically this is primary concern in abdominotheracic procedures in small children]
4. Short-term cosmetic risks (e.g., epilation)

Special concern:

1. Pregnancy (pregnancy test required for many procedures that potentially deliver high doses to uterus – e.g., hysterosalpingogram)

Radiation Risk to Pediatric Patients is a Special Problem!

“Children are not small adults”
— Keith Strauss

Diagnosis of Radiation Injury

- Skin absorbed dose must be high (beam mostly fixed on same skin site)
- Must be located at entrance beam site
- Temporal patterns must fit with progression of injury
- Pattern must match collimation in size and shape (with consideration to movement of beam during procedure)
- Biopsy generally unnecessary and to be avoided if possible
Why do we not feel the effects of X rays that cause such effects?

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The following facts are presented to substantiate the possibility that, in certain circumstances, it [ionizing radiation] may play a part in the development of mammary carcinoma.

Patients were treated for TB by fluoroscopically guided artificial pneumothorax.
Irradiation contributed to development of mammary cancers based on:
• Correlation between cancer site and site of radiation delivery
• Correlation with delivery of high radiation dose
• Unusual younger age of onset and
• Support from animal studies.

Conclusion

What Effect Did Federal Regulations Have on Safety during the 1960’s to 1980’s?
• Regulated Manufacturing of Medical Radiation Producing Devices
• Put limits on fluoroscopy output
• Established the five-minute timer
• Placed requirements on self-shielding of X-ray tubes
• Placed requirements on collimation
• Placed Requirements on distance of X-ray source from patient
• Placed requirements on radiation penetration through image receptor
• Required that the beam not extend outside the useful imaged area

Result:
• Culture of safety gradually improved
• Injury to personnel diminished to very small numbers
• Radiation disease no longer evident in workers

But:
• Use of medical fluoroscopy was primarily diagnostic
• Physicians generally left the room during acquisitions (cine or film changer series)

And:
Radiation outputs were self limited by early X-ray tube technology, slow film processing and time-consuming image management.

This led to:
A FALSE SENSE OF SECURITY

ABOUT THE SAFETY OF FLUOROSCOPY
Today:

- Medical fluoroscopy extensively used to guide therapeutic procedures
- Physicians often at patient side during digital acquisitions

And:

Radiation outputs are virtually limitless with immediate image processing

Recognizing radiation injury and effects

Characteristics of radiation injury

Fluoroscopically Guided Interventional Procedures: A Review of Radiation Effects on Patients’ Skin and Hair
Stephen Balter, PhD, John W. Hopewell, DSc, Donald L. Miller, MD, Louis M. Wagner, PhD and Michael J. Zelefsky, MD
February 2010 Radiology, 254, 326-341.

Recognizing radiation injury and effects

Characteristics of radiation injury

Some aggravating physical or clinical factors

- Coexisting diseases or conditions
  - Siderodermia; systemic lupus erythematosus; possibly rheumatoid arthritis;
  - Hyperthyroidism; poor nutritional status; compromised skin integrity
  - Diabetes mellitus – though to negatively impact recovery from radiation damage
- Genetic factors
  - Heterozygous for the ATM gene; Fanconi anemia; Bloom syndrome;
  - Xeroderma pigmentosum; Familial polyposis; Gardner syndrome;
  - Hereditary malignant melanoma; dysplastic nevus syndrome;
  - Neurofibromatosis; Li-Fraumeni syndrome; Hereditary retinoblastoma
- Medication use
  - Actinomycin D; doxorubicin; bleomycin; 5-fluorouracil; methotrexate; when given in conjunction with radiation therapy: paclitaxel, docetaxel, and possibly tamoxifen can result in cutaneous toxicity
- Radiation history
Radiation Risks

Deterministic Risks to Skin

Collagen vascular disease

Figures withheld

Gironet et al, 1998, Ann Dermatol Venereol, 125, 598 - 600

Wagner et al, 1999, Radiology, 213, 773 - 776

Figures withheld

Transient erythema

Table 1

<table>
<thead>
<tr>
<th>Tissue Reactions from Single-Delayed Radiation Exposure to Skin of the Neck, Trunk, or Abdomen</th>
<th>Acute Radiation Injury (%)</th>
<th>Late Radiation Injury (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose (R)</td>
<td>Prompt</td>
<td>Early</td>
</tr>
<tr>
<td>0 - 2</td>
<td>No erythema effects; epidermis thickened</td>
<td>No erythema effects; epidermis thickened</td>
</tr>
<tr>
<td>2 - 5</td>
<td>Transient erythema</td>
<td>Transient erythema</td>
</tr>
<tr>
<td>5 - 10</td>
<td>Transient erythema, telangiectasia</td>
<td>Transient erythema, telangiectasia</td>
</tr>
<tr>
<td>10 - 20</td>
<td>Transient erythema, telangiectasia; telangiectasia</td>
<td>Transient erythema, telangiectasia; telangiectasia</td>
</tr>
</tbody>
</table>

Note: Applicable in normal skin of patients undergoing radiation treatment in the treatment of cancer. The table is for reference use only and should not be used as a substitute for clinical judgment.

References:
Gironet et al, 1998, Ann Dermatol Venereol, 125, 598 - 600
Wagner et al, 1999, Radiology, 213, 773 - 776

Figure withheld
Note: This is an example of depilation in the scalp. I have no images of depilation in other body locations that are validated as caused by radiation.


TJC Sentinel Event
Three TIPS procedures in 1 week in type II diabetic. Total procedure time 13 - 16 hours.

Several months after 3rd angioplasty
5 months after third angioplasty
22 months after third angioplasty

Recent communications on radiation injury
- As you know, radiation is the gift that keeps on giving.
- After several weeks of having a different kind of pain on top of his usual ongoing pain, K had an MRI, showing 13 fractures, posterior T9, possible nonunion, and a fracture at posterior T8.
- With his debilitating ongoing pain, K does very little in the way of physical activity so it is baffling to try to figure a cause of two fractured ribs. The doctor who did the surgery for K's latissimus flap diagnosed it as osteoradionecrosis.
- Ribs T9 ad T8 are in direct line of what he figures to be the strongest blast of radiation from K's two heart ablation procedures.
- It has been over four years since his first ablation procedure and over three years since the latissimus flap surgery.
- At this point K is not certain what his next step will be to fix the fractured ribs; there are a few options, none of which are attractive to him.
- In your studies have you come across a delay in radiation injury to the ribs? And if so, do you know how the injury was addressed? Or once the radiation starts its grip on the ribs, how long will it continue to cause damage? If you are aware of anyone who has gone through, or is going through, this particular injury, could you please ask that they contact us?
Dose in bone at diagnostic energies is about 3-4 times greater than that in soft tissue due to the photoelectric interaction in calcium.

I really don’t know how much more of this I can stand... do you have any idea looking at the photos, what I might be up against? It is so amazing but it seems I know more about my condition than all the doctors I have been to... HOW CAN THAT BE???? do you have any stats on how many people suffer thru this????

Former major league professional athlete

Cataracts among Chernobyl Clean-up Workers: Implications Regarding Permissible Eye Exposures

Worgul BV, Kundiyev VI, Serdyenko NM, Dzhukhak VV, Vitto PM, Medvedovsky G, Bakhanova EV, Jurik AK, Knyshchenko VT, Musiyachenko NI, Stylo SA, Vitto OP, Xu S, Xue X, Shore RE


- Prospective study of 8607 Chernobyl clean-up workers assessed at 12 and 14 years after exposure
- Cohort young and prevalence of cataracts prior to clean-up assumed similar to prevalence of age-dependent cataract in non-clean-up cohorts.
- Baseline reference was individuals exposed to less than 100 mGy.
- Dose response effect found
- Threshold for induction of Stage 1 opacities ~350 mGy, perhaps less, and not in excess of 700 mGy.