The Nature of Radiological Terrorism

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Goiânia, Brazil, 1987
Population 1.3 million

Abandoned medical clinic in Goiânia contained 1,400 Curie radioactive cesium sources

The radioactive sources were stolen, broken open, and dispersed

Goiânia incident: Equivalent to a large dirty-bomb scenario in Manhattan

- 130,000 people (10% of population) came to ER / temporary screening locations
- 250 (0.2%) were contaminated
- 20 (0.01%) required treatment

Topics that we will cover

- What is radioactivity?
- What is radiation?
- Radiation threat scenarios
- Response issues
- Will it happen?
- Further resources

1895: X rays discovered
1896: Radioactivity discovered

Wilhelm Roentgen
Henri Becquerel and Marie Curie
X rays were immediately big news in New York

“The College of Physicians and Surgeons is using x-rays to reflect diagrams directly on to the students' brains, making a more enduring impression than the normal method of learning”

New York Morning Journal, 1896

Radioactivity

The spontaneous emission of radiations: alpha rays, beta rays, gamma rays, from radioactive materials

Radioactivity: Alpha Rays

Radioactivity: Beta Rays

Radioactivity: Gamma Rays

The Electromagnetic Spectrum

Interaction of alpha, beta, gamma rays with matter: Ionization
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Alpha, beta and gamma rays

Radiation vs. Radioactive Materials

- Radiation: energy transported in the form of particles or waves (alpha, beta, gamma, neutrons)
- Radioactive Materials: material that contains atoms that emit radiation spontaneously

External Contamination

- Radioactive material (usually in the form of dust particles) on the body surface and/or clothing
- 80-90% typically removed by removing clothing

Removing internal contamination is more problematic

Exposure vs. Contamination

External Exposure: irradiation of the body from external source

Contamination: radioactive material on patient (external) or within patient (internal)

Radiation Dose

- Measured in Gray (Gy) or milli-Gray (mGy)
- Equivalent dose is measured in milli-Sievert (mSv)
- For our purposes, 1 mGy = 1 mSv
- Old dose units are the rad and the rem
  - 1 rad = 10 mGy;
  - 1 rem = 10 mSv
- Average background radiation dose is 3 mSv/year
- A mammogram produces about 0.01 mSv
- A CT scan produces about 10 mSv.
Radioactivity

The activity (strength) of a radioactive source is measured in Curies (Ci) or Becquerels (Bq)

- $1 \text{ Bq} = 1$ radioactive disintegrations / sec
- $1 \text{ Ci} = 37 \text{ GBq} = 37$ billion disintegrations / sec

The Principal Medical Hazards of Ionizing Radiation

Early (days / weeks) effects of high doses
- Damage to the blood forming and gastro-intestinal organs

Later effects of high and low doses
- Cancer risks
- Hereditary risks
- Effects on the developing embryo / fetus

Long-Term Radiation Risks

Teratogenic risks
order of magnitude larger than
Carcinogenic risks
order of magnitude larger than
Hereditary risks

Radiation Threat Scenarios

- Nuclear accident
- Nuclear device
- Attack on nuclear power plant
- Dirty bomb

Nuclear Accident

Risk
- Fallout of fission products

Outcome
- Long-term carcinogenesis

Likelihood
- Fairly small
  - Chernobyl
  - Windscale
  - Three Mile Island

Nuclear Device

Risk
- Exposure to $\gamma$ rays and neutrons
- Fallout of fission products

Outcome
- Large number of acute deaths
- Long-term carcinogenesis

Likelihood
- Remote
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Attack on a nuclear power plant

**Risk**
- Attack on the reactor itself
- Attack on stored used fuel elements
  - Release of fission products: I-131, Cs-137, etc

**Outcome**
- Unlikely to involve acute deaths
- Long-term carcinogenesis

**Likelihood**
- Extremely unlikely

Dirty Bombs

**How available are the radioactive materials?**

Dirty Bombs (Radioactive dispersal devices, RDD)

**Risk**
- Release of radioactive cesium, cobalt or americium
- Small number of contaminated people
- Large number of very slightly contaminated people
- Psychological chaos (many frightened people)

**Outcome**
- Unlikely to result in acute deaths
- Risk of long-term carcinogenesis

**Likelihood**
- Likely

Smuggling of potential dirty bomb ingredients is increasing

Types of radioisotopes involved in smuggling incidents, 1993–2005

Radioactive Dispersal Device (RDD)
November 1995

Moscow, Russia -- A group of Chechen rebels contacts a Russian TV station to claim that they have buried a cache of radiological materials in Moscow's Ismailovsky Park. There, the authorities find a partially buried container of radioactive cesium.

December 1998

Argun, Chechnya – A container filled with radioactive materials found attached to an explosive mine hidden near a railway line. It is safely defused.

The location is Argun, where a Chechen group, led by Shamil Basayev, operated an explosives workshop.

January 2003

Herat, Afghanistan -- Based on evidence uncovered in Herat, including detailed diagrams and computer files, British intelligence agents conclude that Al Qaeda has succeeded in constructing a small dirty bomb, though the device has not been found.

March 1998

Greensboro, North Carolina -- Nineteen small tubes of cesium are taken from a locked safe in Moses Cone Hospital. The total activity was 22 Gbq (0.6 Ci).
Each tube was three-quarters of an inch long by one-eighth of an inch wide and were used in the treatment of cervical cancer. The cesium is never recovered.

November 2006

London: Dhiren Barot sentenced to life imprisonment

His "radiation dirty bomb project" was based on an incident in France when a truck carrying 900 smoke detectors caught fire, provoking concern about the radiation exposure.

Barot wrote: "If something so small and simple such as 900 burning smoke detectors could cause so much havoc, then by increasing the amount used, the possibilities are good"

"The radiation project should use around 10,000 smoke detectors and either set them alight or place them on top of an explosive device."

"The burning has the potential to affect around 500 people... as soon as we realised this... we concluded that it deserved to be an independent project in its own right."
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March 2002
Nucor Steel Mill, Hertford, NC

- 2 Ci cesium industrial gauge found on scrap metal conveyor belt
- Traced back to a batch of four belonging to a bankrupt Baltimore chemical company. Three have been located.

Small Dirty Bomb (RDD):
2 Ci cesium source + 10 lb TNT

Inner Ring: One cancer death per 100 people due to remaining radiation (typical dose 25 cGy)
Middle Ring: One cancer death per 1,000 people due to remaining radiation (typical dose 2 cGy)
Outer Ring: One cancer death per 10,000 people due to remaining radiation (typical dose 0.2 cGy)

EPA suggests decontamination

Moisture Density Gauges, contain small quantities of americium-241 and cesium-137
About 22,000 in use in the US.
About 50 per year reported as missing

Large RDD:
1,300 Ci Cs-137 source released in Los Angeles

4-day dose (internal + external) Release: 1.3 kCi Cs-137 RDD with 5 lbs high explosive

<table>
<thead>
<tr>
<th>Area (km²)</th>
<th>Dose (rem)</th>
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<tbody>
<tr>
<td>0.01</td>
<td>4.4</td>
</tr>
<tr>
<td>0.05</td>
<td>0.8</td>
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From B. Buddemeier, UCRL-PRES-149903 (2007)

Small and large dirty bombs (RDD: Radioactive dispersal device)

- Small RDD: High explosives dispersing 0.1 to 10 Curies
- Intermediate RDD: High explosives dispersing 10 to 1,000 Ci
- Large RDD: High explosive dispersing 1,000 to 10,000 Ci

Large RDD:
1,300 Ci Cs-137 source released in San Francisco

Deposit Contamination
Release: 1.3 kCi Cs-137 RDD with 5 lbs high explosive

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
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<tbody>
<tr>
<td>20</td>
<td>Take measures to prevent cross contamination</td>
</tr>
<tr>
<td>2</td>
<td>0.8</td>
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Health-Care Provider Response to a Radiological Event

Almost all the individual presenting at ER / clinic will not require treatment

- 1987 radiation incident in Goiânia, Brazil, a city with about the same population as Manhattan.
- In the first few days after the incident became known, 130,000 people (10% of the population) came for screening, of whom 20 required treatment.

RABIT: Rapid Automated BIodosimetry Tool

- Fully automated ultra high-speed robotic biosimetry workstation.
- Automates two well-established manual assays, γ-H2AX and micronucleus
- One fingerstick of blood
- No human intervention

The main technical innovations are:

1) Use of smaller samples – single drop of blood from a capillary finger stick
2) Complete automation of biology and imaging in multi-well plates
3) Innovations in high-speed imaging

The Need for High-Throughput Radiation Screening

After a radiological event large, tens or hundreds of thousands of people will need to be screened within a few days for radiation exposure...

a) because of the medical- and resource- driven need for triage
b) because active reassurance measures are an effective means of reducing mass panic

"A frenzy can fade if the public believes government is being honest"

New York Times, March 26, 2006

γ-H2AX vs. Micronuclei

<table>
<thead>
<tr>
<th>γ-H2AX</th>
<th>Micronuclei</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Same day processing</td>
<td>• 70 hour processing</td>
</tr>
<tr>
<td>• Highly linear with dose</td>
<td>• Slightly non linear with dose</td>
</tr>
<tr>
<td>• Signal lasts only ~36 h</td>
<td>• Signal stable for years</td>
</tr>
<tr>
<td>• Amenable to high-throughput automation</td>
<td>• Amenable to high-throughput automation</td>
</tr>
</tbody>
</table>

Concept of Use

γ-H2AX vs. Micronuclei

Time 0 h – 36 h

Center for High-Throughput Minimally-Invasive Radiation Biodosimetry

- Columbia University
- Arizona State University
- Georgetown University
- Translation Genomics (TGen)
- University of Pittsburgh
- National Cancer Institute
- Sionex Corporation
- NYC Department of Health
- University of Bern

www.cmcr.columbia.edu

An RDD in a big city: Will it happen?

"Many experts tell us the question is not whether, but how soon ... we will see, for example, a 'dirty bomb' detonated in central London, or some other major capital"

Kofi Annan, UN Secretary General, London, Feb 2005
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**Bottom line**

In the event of a radiological event, medical centers in major cities need to be able to quickly assemble a competent team of health care providers, physicists and administrators / communicators.

**The real bottom line**

- The threat of radiological terror is real
- Most scenarios will present major organizational challenges

**We need to be prepared for a radiological incident**

- Facilities should plan in advance and include procedures in their Disaster Plan

2002 AHA Survey
46% of hospitals did not have radiological terrorism in their disaster plan.

- Everyone needs training!

**The real bottom line**

- The threat of radiological terror is real
- Most scenarios will present major organizational challenges
- The answer:

**Selected further information**

CDC and OSHA have very good starting websites:

Documents:
- American College of Radiology / ASTRO:
  - "Disaster Preparedness for Radiology Professionals"
- NCRP Report #138, 2001
  - "Management of Terrorist Events Involving Radioactive Material"