• Very complicated machines that if not operating properly could cause serious injury to patients.
American Association of Physicists in Medicine (AAPM) Guidelines

- TG-51 LINAC Dose Output
- TG-66 QA for CT scanners
- TG-114 MU Calculations
- TG-119 Treatment planning systems
- TG-120 IMRT QA
- TG-142 medical linear accelerators

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Task Group 142 report: Quality assurance of medical accelerators

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- University of Texas, Houston, Texas
- John B. Dunch
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---

Daily QA ~ 30 minutes

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Non-IMRT</th>
<th>IMRT</th>
<th>325/325</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lip NSP index continuity (all energies)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Dose Energy Continuity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring required daily</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear localization</td>
<td>2 mm</td>
<td>12 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Distance between (EE) &amp; (EE)</td>
<td>2 mm</td>
<td>2 mm</td>
<td>2 mm</td>
</tr>
<tr>
<td>Collimator air indicator</td>
<td>2 mm</td>
<td>5 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Safety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose stopcock (shut off)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose during safety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allen (realistic)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto mA (realistic)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative air monitor (total)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam on indicator</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Monthly QA ~ 4 hours

Yearly QA ~ 4 days

The report of Task Group 100 of the AAPM: Application of risk analysis methods to radiation therapy quality management

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Some key points from TG-100

To prevent failures in RT a QA program should have:

- Standardized procedures.
- Adequate staff, physical, and IT resources.
- Adequate training of staff.
- Maintenance of hardware and software resources.
- Clear lines of communication among staff.

QA Standardization

Procedure standardization
- Well tested QA procedures that are uniformly used across different medical centers to ensure patient safety and to allow comparison of results.
- **STATUS: partially addressed**
  - Task groups have limited user input and feedback.
  - Do not keep pace with rapid technology changes.

Data standardization
- A common vocabulary is needed to communicate between people and computer systems.
- **STATUS: not addressed**

Paper

- Data is safe with redundant backup systems.
- Data can be easily extracted remotely for analysis.
- Many types of data (DICOM) can be stored.
- Complex algorithms can be used on the QA system.
- The QA system is operating system independent.
- Data is in a standardized format allowing comparison across multiple institutes.
- Data taking procedures are standardized.
Excel

- Data is safe with redundant backup systems.
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Software

- Data is safe with redundant backup systems.
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- Complex algorithms can be used on the QA system.
- The QA system is operating system independent.
- Data is in a standardized format allowing comparison across multiple institutes.
- Data taking procedures are standardized.

Methods

- Amazon EC2 cloud
- Flask web framework
- MongoDB database
- Python algorithms
- Ubuntu server
- HTML/CSS
• QA protocols (forms) can be easily created by any user or groups of users (social collaboration).
• All forms can be shared with the group or community.
• Preexisting QA forms can be either forked or upgraded.
• Metrics are used to track the performance of QA forms to indicate popularity.
• The hypothesis is: Through multiple user collaboration certain forms will gain widespread popularity and form a type of QA standardization.

Forms

• Forms can be considered a box that hold a set of parameters.
• All users can create or modify forms.
• The owner can set sharing privileges.

class Form:
    author = the owner
    sharing = private, group, institute, or public
    devices = a list of compatible devices (truebeam, trilogy, )
    tags = a list of tags (mv, mechanical, dosimetry, etc.)
    version = version of form
Form Version Control System

- Users can socially collaborate on building QA protocols.
- Users can comment on forms.
- Any changes to a form that is in use will result in a new version.
- To customize a form a user must first fork it.
Database

- Structured Query Language (SQL) must have a fixed schema. Issues with dynamically changing content.

MongoDB was first released in 2009 and is a schema less database system.

- Instead of tables each entry is similar to a Javascript Object Notation (JSON) like object.
- The number of fields, content and size of the document can be differ from one document to another.
- Allows embedding of data files (DICOM, JPEG, PDF, etc.).

Tasks

- Tasks assign a form and users to a machine.
- Created by the group manager.
- Allow notification to task members (e-mail) when a task is completed.

```python
class Task:
    form = a specific form
    machine = a specific machine
    users = a list of users assigned to the task
```
Records

• Save a QA task’s values to the database.
• Created by all users.

class Record:
    author = the user who created the record
    approver = the user who approved the record
    form = the form
    machine = the specific machine QA was performed on.
    status = pass, warning, fail, or incomplete
    values = list of parameters together with associated inputs.

Records status is color coded (red: danger, yellow: warning)
Modules

- Any user can contribute algorithms provided that they are written in Python.
- Algorithms are run as asynchronous jobs based on a queue system in order not to interfere with web site responsiveness.
- Communication of data between algorithms and the website are through JSON.
Universal phantom algorithm

- Use of Scalable Vector Graphics (SVG) is an XML-based vector image format for two-dimensional graphics.
- Allows both phantom structure and function to be defined in a single file.
QA Standardization

Procedure standardization
• Well tested QA procedures that are uniformly used across different medical centers to ensure patient safety and to allow comparison of results.
• STATUS: partially addressed
  • Task groups have limited user input and feedback.
  • Do not keep pace with rapid technology changes.

Data standardization
• A common vocabulary is needed to communicate between people and computer systems.
• STATUS: not addressed

Data Standardization

• Need a method to find specific QA data across many user created QA forms.

Ontology

• Traditionally a branch of philosophy that deals with questions concerning what entities exist and how such entities may be grouped, related within a hierarchy, and subdivided according to similarities and differences.

• Describes a set of entities and their relationships (X marriedTo Y; or A worksFor B; or C locatedIn D, etc.).

Parmenide (515 BC) was among the first to propose an ontological characterization of nature.
**Taxonomy**

- **Taxonomy is a hierarchy of concepts**

- **Systemized Nomenclature of Medicine - Clinical Terms (SNOMED-CT)**
  - Concepts: 440,408
  - Depth: 16 levels
  - Relations: 440,408

- **International Classification of Diseases (ICD)**
  - Concepts: 12,417
  - Depth: 4 levels
  - Relations: 12,416
  - It was developed by the DICOM Standards Committee, whose members are part of the American College of Radiology (ACR) and The National Electrical Manufacturers Association (NEMA).

- **Medical Subject Headings (MeSH)**
  - Concepts: 80,689
  - Depth: 14 levels
  - Relations: 112,463
  - NEMA holds the copyright to this standard.

---

**Digital Imaging and Communications in Medicine (DICOM)**

- It was developed by the DICOM Standards Committee, whose members are part of the American College of Radiology (ACR) and The National Electrical Manufacturers Association (NEMA).

- NEMA holds the copyright to this standard.
Folksonomy

- Classification system based on keywords that establish categories without stipulating or necessarily deriving a hierarchical structure of parent-child relations among different tags.
- Widely used on the internet for classifying photos, videos, podcasts, tweets, scientific papers and others (Flickr and Twitter).
- Tags are a single word electronic label.

Data Standardization

- A QA input parameter is defined as a combination of lower case tags. Example: “image” “mv” “contrast”
- The hypothesis is: The total amount of parameters need to define all QA inputs will converge to a finite set over time.

Tags

- To make QA data human friendly in terms of searching and identification a combination of predefined ‘Tags’ are attached to each QA input parameter.
- To prevent misspellings, synonyms, singular/plural and compound words only certain people can create tags.

```python
class Tag:
    id = 12-byte hexadecimal (507f1f77bcf86cd799439011)
    name = 20 character string (image, mv, contrast, etc...)
```
Parameters

- Parameters form the entire basis of the QA system.
- Each QA input is tied to a specific parameter.

```
class Parameter:
  id = 12-byte hexadecimal (507f1f77bcf86cd799439011)
  type = file, number, string, etc.
  tags = A combination of tags (image, mv, contrast, etc...)```
Legal and Security

- From discussions with HIPAA and IT groups, data storage on a cloud server is permissible provided that there is absolutely no chance of patient data residing on the cloud.
- Encrypted communications (HTTPS).
- Weak passwords forbidden.
- Passwords are encrypted.
- Login attempts are rate limited.
- Cross-Site Request Forgery (CSRF) protection.
- Non-SQL database avoids SQL injection.
- Automatic daily backups of database.

Conclusion

- A unified QA data management system has been successfully created and put into clinical use.
- Online social collaboration has shown to be effective at forming QA protocols.
- To test the concept of social standardization of QA protocols, more medical centers and users need to be added to the system.

Acknowledgments

- All my colleagues at the University of Chicago
- The pylinac project by James Kerns
  https://github.com/jrkerns/pylinac
Systemized Nomenclature of Medicine - Clinical Terms (SNOMED-CT)

Relationships in SNOMED-CT are modelled as a triple of (concept, attribute, concept).