Towards QA Protocol Standardization through Online Collaborative Systems

Rodney D. Wiersma

Disclosures

• Parts of this research has been licensed to Luca Medical Systems

• 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
Daily QA ~ 30 minutes

Monthly QA ~ 4 hours

Yearly QA ~ 4 days
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**
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.
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.
Data Standardization

• Need a method to find specific QA data across many user submitted QA records.

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 works for B; or C located in D, etc.).

Taxonomy

• Taxonomy is a hierarchy of concepts

• Systemized Nomenclature of Medicine - Clinical Terms (SNOMED-CT)
International Classification of Diseases (ICD)
- Concepts: 12,417
- Depth: 4 levels
- Relations: 12,416

Medical Subject Headings (MeSH)
- Concepts: 80,689
- Depth: 14 levels
- Relations: 112,463

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

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.

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

Parameters
Procedure Standardization

- 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.

```python
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.
Database

- 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 website 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.
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 added to the system.
Acknowledgments

- All my colleagues at the University of Chicago
- The pylinac project by James Kerns
  https://github.com/jrkerns/pylinac