Managing CT protocols can quickly become a daunting task considering most hospital networks or imaging centers will have multiple CT scanner platforms running dozens or more different scan protocols. Additionally, to stay up to date with the latest clinical advancements, frequent changes in one’s CT protocols are required. Existing requirements for ACR accreditation mandate the review of several commonly used protocols, but due to recent Joint Commission requirements, now all protocol changes must be documented and reviewed by a site’s CT protocol optimization team.1–3 The average CT protocol at the University of Wisconsin Madison Department of Radiology has over 50 modifiable options for a single phase exam with only three reconstructions. Multiphasic trauma exams, in which each phase has multiple reconstructions (each tailored to a different diagnostic task) can easily require hundreds of unique protocol fields to be modified. Therefore, CT protocol management requires maintenance of thousands of parameters for each scanner. Managing CT protocols is further complicated by the unique configurability of each scanner.

At the University of Wisconsin Madison, we are fortunate to have a large, well-established CT protocol optimization team consisting of multiple radiologists, multiple physicists, a lead CT technologist, a project manager, a team of IT specialists, and four hourly assistants.4 Over the last several years, CT protocol management efforts have been organized by starting a quality management system (QMS) compliant with ISO 9001:2008. As per the internal QMS, protocol changes were already being documented before the new Joint Commission rules came out. The CT protocols document all aspects of scanning a patient as shown in Figures 1 and 2. The protocols provide details on:

- Indication to assist technologists in selecting the proper protocol based on the orderable and notes received by the attending radiologist
- Details on patient prep (eg, oral contrast, creatinine level limits, heart rate monitoring for cardiac scans, etc)
- Instructions for patient positioning
- Intravenous contrast dosages/flow rates/volumes and needle gauges
- Breath coaching instructions
- A description of each phase of the exam
- Technical parameters for each phase of the exam

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At the University of Wisconsin Madison, we are fortunate to have a large, well-
Instructions for each reconstruction and reformat from the original scan data

The correct billing of each exam

Instructions on where to send all images

The AAPM has compiled a summary of the various parameters needed to define a CT protocol. Our protocols contain images when necessary to describe scanner interfaces or positioning. A change to any of the above is considered a change requiring documentation, as changing any of the above can influence the diagnostic utility of the exam. The old method for documenting protocols included individual Microsoft® Word™ documents for each section within the department (i.e., neuro, chest, cardiovascular, body, musculoskeletal, and pediatric). There are several different scanner architectures present throughout the institution, requiring tailored protocols for each scanner as shown in Figure 1. This resulted in duplicate versions in the imaging section protocol documents, one for each scanner model and location combination.

The difficulty of managing the CT protocols was not in assembling the protocols, but in managing and implementing changes. The documentation described in the previous paragraph required hundreds of pages. For every change made, multiple documents had to be edited and reloaded onto computers located next to each of the scanners. Each aspect of this process had to be documented: who requested the change, approval by the CT protocol optimization team (radiologists, physicists, technologists as required by The Joint Commission), detailed descriptions of the change specific for each scanner model, what date and time the change was implemented onto the scanner, and was the change checked for entry accuracy. By far, the most time consuming part of this process was editing the documents. Since multiple protocol change requests can easily pile up and changes cannot always be made on scanners immediately after new protocols are written, there would often be multiple approved versions of protocol documents waiting to be entered onto CT scanners, leading to inconsistent updating of CT scanners. High volume scanners located near the offices of the CT protocol optimization team were slow to be updated due to patient volume limiting scanner access. The same was true for scanners located at offsite locations where the CT protocol optimization team visited infrequently. Consequently, the protocol maintenance process needed to be audited on a scanner by scanner basis.

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Figure 1 - Table of contents view of our CT protocol homepage showing an index listing each section of protocols and links to the protocols tailored to 8 different CT scanner platforms.
Figure 2 - Screen capture of a protocol for imaging of the orbits, specifically looking for a vascular mass or carotid-cavernous fistula. This is a representative example of how each of our ~300 protocol pages are structured and the level of detail given to each of the protocol sections. Each page is tailored to a specific scanner. Links to positioning instructions and other commonly referenced pages are at the sidebar on the left side of the page.
Wiki Implementation

The large amount of documentation required to make and implement protocol changes resulted in changes, even seemingly small ones, taking weeks or months to implement in a manner fully compliant with the QMS. This is why a wiki based solution for protocol management was implemented. A wiki inherently keeps track of all changes, logging who made the changes and when, allowing for editing and viewing permissions to be controlled, as well as allowing protocol changes to be instantly relayed to all scanner locations. While there are multiple versions of wiki software to choose from, the University of Wisconsin Madison chose MediaWiki due to its large support and user base. MediaWiki is well known as the software used by Wikipedia™.

A wiki based solution for protocol management also allows the facility to save time by using the concept of transclusion. Transclusion is the embedding of a web page’s content into another web page. In the clinical practice, it’s very common to use the same IV contrast administration parameters for multiple protocols (ie, non-gated chest abdomen pelvis, gated chest/non-gated abdomen pelvis, retrospectively gated chest, and prospectively gated chest all use the P3T cardiac option on our Medrad (Bayer HealthCare LLC, Whippany NJ) power injector). Other duplicate parameters include kV/mA/pitch/rotation time/slice thickness combinations. These specifications are the main factors determining image quality, and while there are roughly 300 protocols on a single CT scanner, 300 unique levels of image quality are not needed.6,7 Many exams can provide diagnostic quality images for a given indication using the same radiation dose level. For example, our routine abdomen radiation dose level is also appropriate for our flank pain and the parenchymal phase of our hepatocellular carcinoma protocols. Reformat instructions also heavily rely on duplicate parameters. For the vast majority of our body protocols, a sagittal and coronal reformat is created. We always reconstruct this using the same soft tissue kernel, and at the same slice thickness and interval.

Transclusion can drastically reduce the time required for editing protocols. For example, if a single set of parameters is used by ten protocols, it can be modified once, instantly updating the ten protocols. Furthermore, multiple scanners need to be updated for each protocol change multiplying the amount of editing required given a single protocol alteration. Using the wiki transclusion approach, a change to a single parameter used by ten protocols and multiple scanners would be instantly made on all scanners. This has reduced editing time by orders of magnitude.

While not implemented by the team yet, we plan to take advantage of the community editing principle inherent to a wiki and allow technologists, radiologists, residents, fellows, physicians, and imaging managers to suggest changes to protocols. This will mitigate more “paperwork” and put more of the QMS onto the wiki platform.

Results and Recommendations

For those sites thinking of moving to a robust form of protocol management, a wiki based approach is highly recommended. While other formats, such as spreadsheet based systems, allow for linking commonly used instructions similar to the transclusion principle, no other system offers a complete set of robust options for6:

1. Inherent protocol change history
2. User permission for editing privileges
3. Seamless distribution of protocols once changes have been made via a web based interface
4. An environment easily suited for images, tables of technical parameters, and textual instructions
5. Free software with a robust user and support base
6. Totally customizable to fit specific needs—eg, adding additional modalities such as MRI or x-ray fluoroscopy system
7. Having a digital form of one’s protocol parameters makes cross checking what was actually scanned with what should have been scanned possible in a real time automated manner. This checking can automatically detect non-authorized changes to one’s CT protocols6.

In regards to the time commitment of this project, a competent IT individual should be able to get an instance of the wiki software running within a day. The University of Wisconsin Madison has a robust virtual machine infrastructure making allocating resources for the MediaWiki™ server simple. We hired four part time undergraduate biomedical engineering students to assist with the design of the wiki and with entering content. In total, the effort to create and populate the wiki required two days of one FTE IT professional’s time including debugging and support, four days of one FTE of our lead CT technologist’s time, seven days of our CT physicist’s time, and two months of two FTE undergraduates’ time. Commercial provided solutions for CT protocol management are likely to be provided by most dose tracking vendors in the future. However, as mentioned in this article, the real time commitment and cost associated with protocol management is not in the upfront effort but in the continual updating and documenting of one’s CT protocols. We believe a wiki based approach is an effective way to keep one’s protocol management system compliant with external accreditation guidelines and adaptable to needs specific to individual institutions.

For facilities not wishing to follow the master protocol concept as described here, a significantly reduced amount of effort would be required. Organizations that already have an electronic protocol format should be able to copy and paste the protocol content onto a wiki as we have done in a few days of a single FTE lead technologist’s time. Using the wiki in this way would still allow for authorized edits, change logs, and a web based protocol management solution.
This realization would not, however, reduce the time to edit protocols as the wiki transclusion principle outlined in this article would not be used. This approach may be the best fit for facilities without the resources to spend on an effort as outlined here.

For a video demo of the wiki, please visit: https://youtu.be/6QcrE_1zdP4

References

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The authors are all part of the CT protocol optimization team at the University of Wisconsin Madison Departments of Radiology and Medical Physics. This team, in addition to meeting the clinical demands of the University of Wisconsin Madison Hospital’s CT needs, sells CT protocols to GE Healthcare under a licensing agreement.

Acknowledgements: We would like to thank the entire CT protocol optimization team at the University of Wisconsin Madison directed by Dr. Myron Pozniak. The authors or their institution have no plans to commercialize the protocol management wiki described in this article. TPS has research agreements with the CT and service (DoseWatch) divisions of GE Healthcare. All authors supply CT protocols to GE HealthCare under a licensing agreement.
Questions

Instructions: Choose the answer that is most correct.

1. Due to recent Joint Commission requirements, now all CT protocol changes must be:
   a. Documented by a site's CT protocol optimization team
   b. Reviewed by the Joint Commission
   c. Documented and reviewed by The Joint Commission
   d. Documented and reviewed by a site's CT protocol optimization team

2. To stay up-to-date with the latest clinical advancements, how often are changes required in one's CT protocols?
   a. Frequently
   b. Seldom
   c. Once every five years
   d. When Joint Commission accreditation is due

3. The average CT protocol at the University of Wisconsin Madison Department of Radiology has how many modifiable options for a single phase exam with only three reconstructions?
   a. Approximately 20
   b. Over 50
   c. Around 25
   d. Under 35

4. The University of WI Madison has a large, well established CT protocol optimization team consisting of:
   a. Multiple radiologists and physicists
   b. A lead CT technologist and project manager
   c. A team of IT specialists and four hourly assistants
   d. All of the above

5. Over the last several years at the University of WI Madison, CT protocol management efforts have been organized by starting a:
   a. Superior Organization Team (SOT)
   b. Valuable Administration Practice (VAP)
   c. Quality Management System (QMS)
   d. Worthwhile Supervision Board (WSB)

6. The CT protocols provide details on:
   a. Instructions for patient positioning
   b. Breath coaching instructions
   c. The correct billing of each exam
   d. All of the above
7. A summary of the various parameters needed to define a CT protocol has been compiled by:
   a. AAPM
   b. ASHA
   c. LAEB
   d. SITK

8. The old method for documenting protocols included individual Microsoft Word documents for each section within the:
   a. Hospital
   b. Department
   c. County
   d. State

9. The difficulty of managing the CT protocols was not in assembling the protocols, but in managing and implementing changes.
   a. True
   b. False

10. Each aspect of the protocol change process has to be documented, including:
    a. Who requested the change approval by the CT protocol optimization team
    b. Descriptions of the change specific for each scanner model
    c. What date and time the change was implemented on the scanner
    d. All of the above

11. By far, the most time consuming part of the protocol change process was:
    a. Creating the documents
    b. Implementing the procedures
    c. Editing the documents
    d. Researching the data

12. Which of the following will a wiki allow?
    a. Tracking who made changes and when
    b. Editing and viewing permissions
    c. Changes to be instantly relayed to all scanner locations
    d. All of the above

13. MediaWiki is well known as the software used by:
    a. Microsoft
    b. Apple
    c. Wikipedia
    d. Google

14. Transclusion is the embedding of a web page’s content into another:
    a. Webpage
    b. Network
    c. Emoticon
    d. Site

15. There are roughly ___ protocols on a single CT scanner.
    a. 135
    b. 247
    c. 300
    d. 680

16. In regards to editing protocols, transclusion can:
    a. Increase time
    b. Maintain stability of time
    c. Drastically reduce time
    d. Has no effect on time

17. A wiki based approach offers a complete set of robust options for:
    a. Inherent protocol change history
    b. User permission for editing privileges
    c. Free software with a robust user and support base
    d. All of the above

18. A competent IT individual should be able to get an instance of the wiki software running within:
    a. An hour
    b. A day
    c. A few weeks
    d. A month

19. The real time commitment and cost associated with protocol management is not in the upfront effort but in the continual updating and documenting of one’s CT protocols.
    a. True
    b. False

20. Organizations that already have an electronic protocol format should be able to copy and paste the protocol content onto a wiki allowing for:
    a. Authorized edits
    b. Change logs
    c. Web based protocol management solution
    d. All of the above