tocol optimization team. By logistical we refer to information pertaining to realistic patient breath hold times for different-aged patients and realistic patient breath hold times for patients with different clinical indications.

In addition, our lead CT technologist is responsible for controlling revisions within our actual CT protocol documents and keeping track of the numbering of our protocols. We maintain uniform numbering for all protocols across all of our scanners. We recommend institutions also strive to maintain uniformity in naming and numbering [15,22,26] of protocols across all of their scanners as this reduces the chance of error as CT technologists move from scanner to scanner.

11.3.5 IT Support

Failure to recognize the importance of informatics personnel can hamper the efforts of a CT protocol optimization team. For sites that have IT policies that restrict the use of scanner-side computers, posting digital copies of protocols scanner side may be impossible. If protocol changes are dependent on changing ordering sets or billing options, and IT support staff take months to realize requested changes, protocol updates will suffer.

We currently house our protocol documents on a server with an implementation of Wikipedia wiki software. We also manage our CT protocol optimization team's efforts and document protocol changes on an instance of Sharepoint (Microsoft Corporation, Redmond, WA). Lastly, we rely on IT support personnel from our hospital EMR system Radiologist Information Service (RIS) and billing divisions to integrate protocol changes with ordering and billing. We also rely on informatics personnel from our PACS and informatics security teams to assist with getting data to and from our CT scanners. Members of these informatics teams are not present at any regular CT protocol optimization meeting; they receive requests via our institutional informatics request ticketing system. The need for IT support is not unique to our practice. All practices will need to bill, interface with an RIS, monitor dose, send studies to third-party post-processing companies, and interface with PACS and 3D processing network locations.

11.3.6 Applications Specialist

The knowledge of an application specialist (apps) should be a valued input to a CT protocol optimization team. The knowledge of apps will reflect the latest product options and instructions from your CT vendor. Apps receives training directly from factory sources who are intimately involved with the creation of new scanner features. Therefore, the input of apps in the creation of new CT protocols and the updating of existing protocols is essential. The ability of apps to build protocols varies by country due to local laws regulating the ability of apps to adjust scan settings technologists will use on patients. Therefore, you may find some sites who solely rely on apps to build their entire protocols, while others do not let their apps personnel touch their protocols. Apps can also assist in disseminating optimized protocols from site to site. Apps will often have trialled protocol parameters your CT protocol optimization team may be considering at other sites. Therefore, involving apps may mitigate the need for some in-house optimization work when apps shares optimal scanner settings and scanning workflows learned at other sites.

11.4 Components of a Protocol

Medical imaging protocols are complex sets of instructions. Protocols in medical imaging involve instructions aimed at technologists, nursing staff, physicians, and imaging devices.

Too often protocols are focused on the instructions for the imaging device and are light on the instructions for the personnel interacting with the device. This is evident by looking over many published protocols that are largely made up of tables or lists of technical acquisition and reconstruction parameters that are preprogrammed into an imaging device. Our goal in this section is to capture all decisions influencing an imaging protocol. For example, many sites have guidelines on beta blocker use for cardiac gated exams. These guidelines should be part of the imaging protocol. Another common facet of protocols left out of documentation is what reformats to create and what images to send to PACS. Ask any radiologist what causes them to call over to the scanner, and the most common reason is to send over images that were forgotten to be sent. Documenting which protocols need which images/reformats sent over is an easy way to mitigate such calls. Even for sites using the "auto reformat" or "auto send" features of their scanners, documenting which protocols and which series/phases within those protocols have these automatic features turned on is needed when setting up new imaging equipment to copy existing equipment. Further motivating the need for robust protocol documentation are top-down requirements from accreditation agencies, such as the American College of Radiology (ACR) and The Joint Commission (TJC). Both of these bodies require protocols to be documented and changes to be recorded.

Tables 11.1 through 11.5 represent all the fields we consider important to document. These fields are part of a template for CT imaging protocols available online at www.protocolshare.org, a website founded by the author to enable the free and open sharing of medical imaging protocols. Interested readers should also be aware of DICOM Supplement 121 which details the technical acquisition parameters in a vendor-neutral manner needed to fully capture the essential elements defining a CT protocol [27].

If you are new to documenting CT protocols, we recommend convening a meeting of a radiologist, a CT technologist, and a physicist. Use Tables 11.1 through 11.5 to record the needed protocol parameters for your institution's protocols. These tables are robust in that they include a wide range of information that likely will not be applicable for all practices and protocols. Using these tables is a great thought stimulator to ensure your site's protocol documentation is considering all facets of a CT protocol. For guidance on the layout of the protocol documentation, see the AAPM CT protocols, which are freely available online.† Keep in mind who will be interacting with the protocol on a daily basis. Technologists will be interacting with the protocol documentation on a daily basis. This is why the protocol template fields defined in Tables 11.1 through 11.5 include an entire section on workflow. The workflow information in Table 11.5 is meant to contain in a single table all of the needed scan time information a technologist needs to perform the exam. Figure 11.2 depicts an example layout of protocol information.

† www.aapm.org

Table 11.1 Compliance components of a CT protocol

Section	Comment
Contributors	Provide the names of the people putting together this protocol. This author list should reflect those individuals responsible for creating the protocol content. If the content of the protocol is novel, refer to the creators of the protocol in the Design Philosophy section of this template. You may also list the name of an organization, for example, "University of XXX CT Protocol Optimization Team."
Protocol Name	A protocol name should appear in this box. This name should be descriptive of the protocol. The convention usually adopted in CT is to have the name refer to three things: the body part being imaged, the use of contrast, and sometimes the name of the indication commonly or usually associated with the protocol. If your center appends protocol names with the last date they were edited or checked, you may include that information as well. Dating your protocols in the name field will enable easier sharing of your protocol across a large hospital network and facilitate data analysis from dose monitoring programs.
RadLex Playbook Name and ID	A valid RPID number and name should appear in this box. The RSNA has published a naming system for CT protocol names. Almost all CT protocols can be mapped to this standard. This mapping is commonly needed for centers with more than one CT scanner who wish to combine dose monitoring data or for quality improvement, billing, workflow analysis, or other reasons. Information about the RadLex Playbook can be found at https://www.rsna.org/RadLexPlaybook.aspx. RadLex has provided a playbook browser which can be used to quickly find a matching playbook number. It can be accessed at http://playbook.radlex.org/playbook/SearchRadlexAction.
Clinical Indications	A concise statement of a few sentences should describe the clinical indications this protocols is to be used for.
Design Philosophy Details	A concise statement (a few sentences to a few paragraphs in length) describing the clinical/workflow/technical thinking guiding the development of the protocol.
Academic References	A list of references corresponding to the text given in the design philosophy.
Other Resources	Links to YouTube or other instruction videos, white papers not indexed online, etc. should be provided here. If a link is provided, provide a title for the link that clearly describes what the link contains followed by the full (including the http:// or www.) web address.
Billing Code	Provide a list of CT billing codes (CTP) here.
Billing Notes	Provide any notes pertaining to the billing codes here. Appropriate information to include would be any post-processing steps needed to satisfy billing requirements. For example, "To bill as a CTA, the volume-rendered images must be made from the angio phase of the exam."
RSNA Reporting Template	The title of the template (identical to the one on the www.radreport.org website). Note: the template page provides suggested RPID to be used with this template; please cross check the RPID you used in the protocol name subsection "RadLex Playbook name and number" with the RPID listed here. If there is a difference, you may want to consider editing the RPIDs you provided, but this is not always appropriate.
Dose Table	Most modern CT protocols will employ automatic exposure control (e.g., tube current modulation) that varies as a function of patient size. Additionally, multiple options for patient dose surrogates are in use today. Because of this, there are many options for reporting dose data. The dose metric value for each metric and phantom/patient combination should be placed in a table. Note: for multiphasic exams, the dose from each phase/series/group must be included. Not all of the dose metric and phantom/patient combinations need to be filled out.
ACR	Compliance with any programs should be documented here by listing the program name, for example, ACR Lung Cancer Screening.
OPTN/UNOS	This box should be filled in with the name of the organ covered by the OPTN/UNOS guidelines. OPTN (Organ Procurement and Transportation Network) and UNOS (United Network for Organ Sharing) periodically publish guidelines for CT scanning done in conjunction with organ transplants. For example, see http://pubs.rsna.org/doi/full/10.1148/radiol.12121698 for an example of guidelines for HCC liver imaging.
Device Manufacturer	Compliance with a device manufacturer's protocols should be documented here by stating the name of the manufacturer and the specific device or procedure name. For example, if your protocol meets the slice thickness and reconstruction kernel requirements of a robotic orthopedic surgery device company for a knee replacement, you would document the manufacturer's name and the specific procedure or device name in the protocol.

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Table 11.1 Compliance components of a CT protocol (continued)

Section	Comment
Software (CAD/ Surface Rendering, etc.)	Compliance with a software manufacturer's recommended protocols should be documented here by stating the name of the manufacturer and the specific software package. For example, if your protocol meets the beam energy and slice thickness requirements mandated by a computer-aided diagnosis company, provide the company's name and the specific CAD software package.
Trial/Study/ Publication Details	If this protocol is being used or was used for a specific research paper or study, the paper reference should be included.

Table 11.2 Dose table template. Put dose values in the "Vendor-Supplied Water Phantom" column and the phantom's diameter in column 3; this allows scaling of doses between different vendors' water phantoms based on diameter. The other columns allow reporting of dose measured on standard 16/ 32-cm CTDI phantoms and for documentation of dose metrics from actual patient scans (i.e., from a dose monitoring system).

Series Name	Dose Check Value (NV)				
	Vendor-Supplied Water Phantom	Vendor-Supplied Water Phantom Diameter	16-cm CTDI phantom	32-cm CTDI phantom	Patient Population Data
$CTDI_{vol}$					
DLP					
SSDE					
Effective Dose	n/a				

Table 11.3 Clinical components of a CT protocol.

Section	Comment
Patient Preparation	Patient preparation instructions should be provided. Examples of patient instructions include asking female patients undergoing a chest CT scan to remove their brassier to avoid underwire artifacts. Another example is to have patients undergoing a pelvis CT scan remove their pants if they contain any metal rivets/zippers/buttons. The medication and heart rate monitoring instructions needed for some cardiac gated exams would also be documented here. While the IVC parameters are provided below, the IVC needle placement and gauge details should be provided here.
Oral Contrast Instruction	Provide the total volume, dose per drink, and temporal spacing between drinks. Additionally, provide the contrast agent type (manufacturer), concentration, dosage, and any special mixing instructions.
IV Contrast Instruction	Provide the total volume, flow rate, contrast agent type (manufacturer) and concentration for both the contrast and saline chaser (if used). If using a power injector protocol, provide the make and model of the injector and the specific protocol.
Patient Coaching Instructions	Provide details on patient coaching. For example, provide details on patient breathing instructions or instructions on how to induce a Valsalva maneuver when needed. While patient coaching details are included in the Workflow Details section of the template, this section should contain a more robust version of coaching instructions. The coaching instructions provided in the Workflow table are meant to be a reminder to the technologists during the exam, whereas the instructions provided here should fully convey all needed details of the instructions.
Physician or Nurse Monitoring Instructions	Patient monitoring details should be provided here. If the monitoring physician/nurse is expected to make a mid-exam decision based on the results of the exam (for example, the decision to proceed to the perfusion phase of a stroke protocol may depend on the presence of a bleed detected on the non-contrast series) details on this decision should be provided in this box.
Patient Positioning	Provide details on patient positioning. For example, for musculoskeletal exams that demand high resolution, a note should be made to ensure the anatomy of interest is positioned as close to the scanner's isocenter as possible to maximize the spatial resolution capabilities of the scanner.

Table 11.4 Clinical workflow components of a CT protocol

Section	Comment
Exam Logistics by Series	*One should provide technologists with a high-level overview of what the exam includes. Provide them with concise details needed to navigate a CT exam from CT localizer radiographs to exam end.*
Series Name	Provide a name for each series (i.e., series description or reconstruction name). The series name should be as descriptive as possible and usually describes the contrast phase imaged. For example, a routine three-phase abdomen protocol could have series names of "non-con," "wIVC," and "delayed."
Coaching	Provide a short and concise reminder to the technologist. Provide the full description of the coaching details in the Clinical Components section of your template.
Bolus Tracking	Provide the size and placement of the bolus tracking region of interest. Document details on timing delays associated with bolus tracking and enhancement thresholds in the Technical Acquisition Details section of this template; do not repeat them here.
Scan Ranges	Provide a pictorial or textual description of the scan range, including where to start and stop the scan. For example, a scan of the head may be scanned from the top of the head to the mandible. This could be documented as, "Start above the head; some air should be included in the image volume; continue down to the level of the mandible."
Reformats	
Name	Provide the name of the reformat. Usually, the name consists of the reformat plane and the type of reformat being displayed (recon algorithm/kernel, MIP/minIP, etc.).
Plane	Provide the anatomical plane name.
Type	Provide the reformat type. For example, maximum intensity project (MIP), average, etc.
WW/WL	Provide the window width and level of the reformat.
Thickness	Provide the reformat thickness in mm.
Interval	Provide the reformat interval (distance between adjacent reformat slices).
Source	Provide the source image volume used to create the reformatted view.
Networking Destinations	*Provide a reference to technologists after the exam to facilitate getting the images the right places as quickly as efficiently as possible.*
Series name	Provide the series name. Note: not all series have to be sent to radiologists for review. For example, it may be appropriate to reconstruct thin axial slices for the sole purpose of reformatting into thicker non-axial planes; in such a case, the thin axial slices may not always be sent to radiologists for review. Also note that the destination for networking does not always have to be a PACS; it may also be a computer-aided diagnosis server or a post-processing laboratory.
Destination	Provide the networking destination. Usually, a generic name is all that is needed, like "PACS," "LUNG CAD," or "3D LAB." The actual networking details usually only go into one place on a scanner and do not need to be entered for each exam. Details like AE title/port number and IP address need to be entered onto a scanner's host table.

Table 11.5 Technical acquisition components of a CT protocol

Section	Comment
Scanner Platform	*Scanner options vary greatly between vendors and even within the same make and model via the different available options within a model line. Providing the make and model will ensure the vendor-specific verbiage is correct. Providing the tube power, detector number, and optional packages will enable you and the people you share your protocols with understand how similar your scanners are to each other.*
Make	Provide the vendor name (i.e., Cannon, GE, etc.)
Model	Provide the model name of the scanner.
Tube Power	Provide the maximum tube power rating. Vendors usually report this value on your bid/quote.
Detector Number	Some scanners report a number double the actual number of detector elements (for example, 128 instead of 64). If your scanner reports double the actual number of elements, report this "double number" as this is the number that is commonly cited when referring to the scanner in the community.

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Table 11.5 Technical acquisition components of a CT protocol (continued)

Section	Comment
Gating/Perfusion etc. Packages	Provide the vendor-specific name of the cardiac or respiratory gating options your scanner has enabled. Provide the vendor-specific name of any special perfusion or cine options your scanner has enabled (for example, not all scanners ship with a shuttle mode for perfusion imaging). State any other special options needed to perform the protocol. An example of another option would be any special dual-energy processing modes. In general, options included here are options the user has to pay "extra" for when buying a CT scanner.
Acquisition Details	*Due to the complexity of modern automatic exposure control systems and other vendor-specific nuances, many acquisition parameters behave differently based on how other seemingly unrelated parameters are set. Therefore, this part of the template aims to capture all possible acquisition and reconstruction options.*
Scan Type	Provide the scan type. Scan types should be one of the following: CT Localizer Radiograph, Axial, Helical/Spiral, Cine, Perfusion, Cardiac Gated, and Respiratory Gated. All of these scan types may also need to have a modifier for dual energy.
kV	Provide the beam energy. If the kV is selected by the scanner based on the patient size, the setting for the kV selection should be provided here. For example, list the min and max allowable kV settings and the iodine contrast strength selector.
Pitch	The pitch used for helical/spiral scanning should appear in this box. For scanners that pick the pitch for you at scan time (i.e., some cardiac gated exams) you can list this parameter as "variable."
Rotation Time	Provide the rotation time.
mA/Effective mAs	Provide the mA or effective mAs. Some vendors only provide one or the other.
Collimation	Provide the collimation or beam width. Give the value as a distance in mm and, if possible, a detector configuration. For example, 40 mm (0.625 x 64).
AEC/TCM Setting	Provide the AEC or TCM setting(s). Examples include noise index, effective mAs, or standard deviation value.
Acquisition Slice Thickness	Provide the slice thickness used for the first or primary reconstruction.
Acquisition Interval (Axial Scanning Only)	Provide the interval used. Note: this interval refers to the distance the scanner will move between axial couch positions.
Acquisition Reconstruction Filter/ Kernel Scan FOV	Provide the filter/kernel for the first or primary reconstruction.
Recon Options	*You will need to document recon options for every reconstruction made from the source data described in the acquisition details section above. It is not uncommon for a single acquisition event to have more than two reconstructions. Some protocols may need to have more than 10 reconstructions to provide the interpreting radiologist the image they require. Due to the ever-growing size of new reconstruction options, do not expect this template will accommodate all future reconstruction options. Currently many vendor-specific options are difficult to classify and group together. Therefore, this portion of the template has a few generic spaces left open for the placement of vendor-specific reconstruction options.*
Recon Name	Provide the reconstruction name. This is the name PACS will label the images within the series description DICOM field. See Figure 11.3 for an aid in choosing this field.
Reconstruction Filter/Kernel	Provide the filter/kernel.
Display FOV	Provide the display or reconstruction field of view.
Slice Thickness	Provide the slice thickness.
Slice Interval	Provide the interval. Note: do not confuse this value with the spacing between adjacent axial/cine/perfusion/cardiac scan's table/couch positions. In general, this value will be equal to or smaller than the slice thickness.
Iterative Denoising Level	Provide the type and strength/level/percentage of denoising.
Recon Options	Provide any reconstruction option not accounted for by another section on this part of the template. For example, you should describe any special beam hardening correction algorithm, motion compensation, registration, dual-energy-specific options, etc. here. More than one box is provided to document multiple options separately. (For example, on a GE Healthcare scanner, you would place the "IQ Enhance" option here.)
WW/WL	Provide the window width and window level used for the reconstruction.