Spreadsheets for Automated Data Collection, Analysis, and Report Generation for Diagnostic Medical Physics: Publicly Available on the World Wide Web

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A library of spreadsheets has been developed to facilitate the practice of diagnostic physics quality assurance. Each spreadsheet follows a standard template and uses the highest ranking controlling authority (within the United States) for pass/fail criteria and testing procedures. Sheets are now available for CT (computed tomography), MR (magnetic resonance), US (ultrasound), screen-film mammography, stereotactic breast, radiographic, fluoroscopic, computed radiography, film digitizer, and display quality control. Use is made of spreadsheet "workbooks" so that each testing event is a single sheet in the workbook. Thus, results over the lifetime of the device are gathered in a single file, and historical control charts are gathered on the first sheet. The spreadsheets are available at <http://radweb.mcis.washington.edu/~sglanger>, and are released under the Gnu (a recursive acronym. Gnu's Not Unix) public license. It is expected that others will add improvements, and they are expected and requested to submit them back to the author to be shared with the diagnostic physicist community at large.

KEY WORDS: Diagnostic physics, quality assurance automation, spreadsheets.

OUR PRACTICE CONSISTS of more than 120 radiographic and fluoroscopic tubes, 7 CT (computed tomography) units, 5 MR (magnetic resonance) units, 10 mammography tubes, 10 laser digitizers, 16 CR (computed radiography) plate readers, 15 US (ultrasound) imagers and 140 picture archiving and communication systems (PACS) displays (cathode ray or flat screen). Until recently, this service was covered by a "quarter" time position. We would find it extremely difficult to comply with the testing schedule required by federal and state regulators as well as our own stringent in-house standards if it were not for the ability to automate much of the data collection, analysis, and reporting.

Numerous investigators have published methods of automated quality control for specific devices.¹⁻³ More recently, medical physicists have become familiar with and use spreadsheets on an almost daily basis—commonly, Microsoft's Excel (Microsoft Corporation, Redmond WA). Numerous controlling authorities use Excel spreadsheets to build data collection templates.⁴⁻⁶ Similarly, many medical physicists use Excel to create template sheets on paper that they can use to record data when testing a unit. While this is helpful, it still requires more work after one has left the test site to calculate HVLs (Half Value Layer) or Coefficients of Variation to determine if the unit has passed the tests.

Vendors such as Radcal, Kiethley, and others have tried to ease the workload by providing dosimeters that can interface with a personal computer via a serial link (Radcal Corporation, Monrovia CA; Kiethley Instruments, Cleveland OH). Often, vendors also provide example Excel spreadsheet routines for calculation of HVL and other factors. However, these examples often spread tests across multiple pages in a workbook, making it difficult to contain more than one day's test results in a single workbook.

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This complicates studying the behavior of, for example, kVp (peak kilovoltage) accuracy over time, because one has to open several workbooks and look at the single datum over multiple sheets.

A more convenient method is to group all tests for a given day on one sheet. Multiple sheets within the workbook then can be used to store the results of numerous testing events. Finally, the resulting control charts (or trendlines) can be displayed on the front sheet of the workbook to provide a history of key performance metrics. In addition, one can create lookup tables in the workbook to contain the pass/fail criteria for the tests and allow the spreadsheet to automatically print out the status of various tests. Furthermore, by assembling tests and results in this way, it is easy to print a summary block of the test results and recommendations for service.

The authors cannot guarantee they are the first to use this concept, and others have published reports on specific efforts for a given modality.⁷ However, many groups that use such tools often are consulting physicists who treat their spreadsheets as a competitive advantage to be guarded. We are (we believe) unique in freely offering (through our web site) a complete suite of quality control workbooks for all major devices in diagnostic imaging built on a consistent design and methodology.

METHODS

For each modality (CT, film-screen mammography, stereotactic breast biopsy, radiographic, fluoroscopic, MR, US, CR, digital radiographic, digital mammography, film digitizer, and displays) a literature search is performed on the relevant AAPM (American Association of Physicists in Medicine), ACR (American College of Radiology), and MQSA (Mammography Quality Control Standards Act) sources to establish comprehensive tests and pass/fail criteria. An Excel workbook template then is created with the second worksheet acting as the scaffold for the unit information, report results summary, and the tests themselves. Areas that require data entry are shaded, whereas all other areas are protected to prevent sheet corruption. Subsequent monthly and annual tests are put on the third, fourth, and subsequent worksheets.

Data are grouped in columns that are related logically. For instance, the first column contains information about the machine (manufacturer, date of manufacture, model, and serial numbers). Below that is a description of the testing equipment and the dates of most recent calibrations

(if applicable). Finally, the bottom of column one contains a summary of all tests on the sheet and a note of pass or fail.

Subsequent columns continue the strategy of grouping related data. For instance, all CT tests involving the body dose phantom are under one heading. Similar rules are applied for other phantoms and procedures. This logical structure assures that tests are performed in the most efficient manner with a minimum of setup and change out times of phantoms or dosimeters.

The first worksheet of the workbook is used to display control charts of key operational parameters (eg, half value layer or glandular dose) over the time covered by the subsequent sheets. By grouping all longitudinal data for a given test in a single plot, it is easy to track the performance of—for example—the average dose of a phototimed anterior-posterior chest over the testing life of the unit. Further, it is easy to compare the performance of analogous units throughout the institution on any parameters of interest.

If needed, the first sheet also contains default operational parameters for the radiation monitor (a Radcal model 9015) that can be coupled to the worksheet via vendor supplied macros.

Finally, sheet one contains the pass/fail limits for the various tests. By analogy with the testing sheets, pass/fail criteria are listed in columns that match the columns on the test sheets. Because the pass/fail thresholds are isolated in this way, it is straightforward to update the entire workbook if the regulating authority changes its acceptance limits (eg, Mammography Quality Standards Act in 2002).

RESULTS

A large library of Quality Assurance workbooks now have been built: general radiographic and fluoroscopic, CT, MR, US, CR, film digitizers, displays, mammography, and stereotactic biopsy units. In some instances, the workbooks still must be considered as works in progress because the ultimate goal is to build sheets that will follow either regulatory or ACR accreditation guidelines. Yet at the time of this writing (for example in CT) the ACR has yet to render final recommendations and the American Association of Physicists in Medicine (AAPM) Task Group 18 has yet to render a final report on display quality control. Thus, the workbooks for such “unfinished” topics follow the “best practice” recommendations available at the time (ie, the AAPM CT task group’s report and the Department of Defense’s Digital Image Network PACS [DIN-PACS] acceptance testing document for displays, respectively). Of course, the goal is to update the workbooks as conditions warrant.

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Section 1: Generators

Medical Physics Survey: R&F
XYZ Medical Center

Inventory

A. Background information

Survey Date: 12 Apr 2001
Room: 204
State Reg. No: WAC 246-225
Unit: Radiographic chest

Equipment	Manufacturer	Date of Man.	Model	Serial Number
Generator	GE	Apr-91	1234-dg-5	3452

Housing:
Collimator:
Tube:
Image Receptor:
Tube Rating: Max Tube kV 120 Max Tube mA 400 Focal Spot (a) mm 1.2, 5

Item	S/N	Calib. Date
Radical 9015 Radiation Monitor Controller	91-0130	Jul-00
Radical 9060 Electrometer	99-0229	Jul-00
Radical 10x5-6 Ion Chamber (6cc)	15385	Jul-00
Radical 10x5-180 Chamber (180cc)	5677	Jul-00
10x5-3CT CT Chamber (3cc)	7928	Jul-00
Keithley 35080A kVp Divider (Mammography)	64419	Jul-00
Gammacell 220 HVL Attenuator Set	6658	na

B. Visual Check List

	Pass/Fail/NA	Action
TFD indicator or marker	P	
Angulation indicator	P	
OVERHEAD	P	
Locks (all)	P	
TUBE	P	
Purpose/collimator	P	
CRANE	P	
Field light	P	
Bucky coater light	P	
High tension cable/other cables	P	
Overhead crane movement	P	
Bucky lock	na	
Cassette lock	na	

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Section 1: Generators

A. Focal Spots (two methods, use one)

Slit Method

Test Tool: slit camera
slit width: 0.001 mm
Object-Image Distance: 20 inches
Source-Object Distance: 20 inches
Technique Factors: Large Focals Small Focals
kVp: 75 75
mAs: 50 50

Notes: Use the focal spot test stand with the film on the table top. Align tube. Make one exposure w/ slit @ to Anode-Cath, rotate slit 90 for 2nd exp. Nominal Size Measured W Calculated % Accept Limit Measured L Cal

	0.6	1.2	0.6905	0.9	1.0
small focal spot	1.2	1.8	1.8485	1.7	2.5

Pass Focal spot, NCRP 99 Focal Spot Recommendations
Recommendations:

Star (uniform single source)

Test tool: star target
Star angle: 2 degrees
Object-Image Distance: 20 inches
Source-Object Distance: 20 inches
Technique Factors: Large Focals Small Focals
kVp: 75 75
mAs: 20 20

Notes: Use the focal spot test stand with the film on the table top. Align tube. Make one exposure for each focal spot, moving film between shots. Nominal Size Image W Calculated % Accept Limit

	0.00	20/NA
small focal spot	0.00 <td>20/NA</td>	20/NA
large focal spot	0.00 <td>20/NA</td>	20/NA

Focal spot, NCRP 99 Focal Spot Recommendations.
Recommendations:

B. mR/mAs Linearity

Technique: 72 SID inches 70 SID inches

Fig 1. A representative sheet from the R&F spreadsheet. The sheet tab indicates that these are data for the 2001 testing cycle. One can see 2 distinct columns: the first (starting at cell A1) contains unit information, calibration dates for the testing equipment, and a visual checklist. Section one groups tests that monitor the x-ray generator and utilize the radiation monitor and kV measuring unit. Section

2 includes collimation tests that require film, making images, and the system continues through section 4. The shaded areas represent data entry points. Unshaded zones are write locked in normal operation to prevent accidental damage to the spreadsheet's data elements and calculations (as can occur if the dosimeter is allowed to acquire dose data and write to new cells each time it is triggered).

Figures 1 through 5 show some subsets of the anatomy of the radiography and fluoroscopic (R&F) workbook. In Fig 1, the upper left corner displays the template type (R&F in this case) and the host medical center. As one looks down the first column, a visual inspection block is displayed for tests that require the user to manually enter "pass" or "fail". The reader also will note that some cells are shaded, whereas most are not. Shaded areas indicate to the user that this is a data entry area. Also, the shaded areas can be written to, whereas the white areas are normally write-locked. The reason for this is to prevent the sheet from being corrupted by a typographic error or a runaway

radiation dosimeter (that may be acquiring data in a mode the increments the readings down the page). If for any reason the user needs to access the white areas, they can become write accessible by "unprotecting" the spreadsheet.

Continuing down the sheet shows the area seen in Fig. 2, a test summary block for all the tests in the remainder of the sheet. This area is automatically completed as the tests in the sheet are performed and can be printed out separately as part of the written report for the device being tested. To the right one can see a table of exposure, time, and voltage values. This information is used for determining voltage accuracy and constructing an exposure per mAs (mil-

Fig 2. Scrolling further down the page from the area shown in Fig 1 displays a summary block that lists the status of all tests in the sheet. To the right, one sees the results of the kV accuracy tests and the regression fit to a mR/mAs vs kV plot.

liAmpere seconds) versus peak kilovoltage plot. This example points out a useful feature of the spreadsheets, in that the same exposure information (exposure, time, and voltage in this case) can be used to perform multiple tests at once (ie, voltage accuracy, timer accuracy, one entry of the exposure reproducibility tests, and exposure per mAs versus kilovoltage). Further, the resulting plot can be fitted with a polynomial whose coefficients can be used to calculate free-in air exposures for standard examination techniques. As a result of making double or triple use of collected data, we estimate the total number of exposures for tube testing has been reduced by over one third from our earlier manual methods - reducing both tube loading and time in the room.

Figure 3 shows the cover sheet of the workbook. This area is a recapitulation of the de-

The regression coefficients are used later on to compute estimated free-in-air doses for the various examinations performed on this x-ray system. Areas left blank on this R&F spreadsheet are not applicable to this unit.

vice's descriptive data and the trend plots of key performance parameters. In this workbook, there is space set aside for 12 years of longitudinal data, although there is no reason that the workbook could not go on to include dozens of test sheets. The shaded area displays the version date and the copyright under which the spreadsheet is released.

Figure 4 also is on the cover sheet, but shows an area normally hidden. This area acts as storage for data that are needed elsewhere in the sheet. For instance, any needed lookup tables (eg, for minimum acceptable half value layers by kilovoltage or operating parameters for the radiation dosimeter) are stored here.

Scrolling to the right of Fig. 4 shows Fig. 5, and the pass/fail values for the various tests are referenced here. This central location makes it easy to update the workbook in the event that

Fig 3. A view of the workbook's cover summary sheet. Trendlines for kVp accuracy and Half Value Layer (HVL) are displayed. Additional data also are plotted for manual and phototimed chest doses. Grouping the data in one place makes it trivial to compare the performance among multiple units.

the controlling authority (say, the American College of Radiology) changes its pass/fail limits in the future for the given modality. Below the first column of pass/fail criteria is also a region for logging the bug/improvement history of the worksheet.

The productivity of our physics group has been considerably increased with the adoption of these tools. Consider a radiographic room. Before adoption of the R&F sheet, it would take approximately one hour to do a full test on the tube, wall, and table Bucky. An additional hour to 90 minutes would be required in plotting values back at the desk and writing the final report. With the spreadsheet combined via a serial link to an external dosimeter and kV unit, it is possible for an experienced

user to perform the same tests in less than 45 minutes. Furthermore, when one leaves the room, the test summary and technique chart—with doses for standard examinations—is complete.

Similarly, in mammography it typically has required 3 hours to do a full room test (not counting film/screen uniformity testing). With the spreadsheet modeled on the MQSA forms, we now require about 2.75 hours, but when we leave the room the report is ready for the MQSA inspector.

The enhanced documentation of the workbooks also strengthens our service position when dealing with vendors. The ability to compare, at a glance, operational characteristics of several similar devices simultaneously

Fig 4. In a hidden area on the cover sheet are lookup tables for various uses. In the particular case of the R&F spreadsheet, it is useful to have the pass/fail criteria for the focal spot and HVL. For example, in Fig 1, the cell O17 is highlighted. It contains the value 0.9, which it knows to be the acceptance width limit for a 0.6-mm focal spot by looking it up in the table above from cell T13. In a similar manner, the HVL test "knows" the minimum acceptable HVL by performing a lookup on the above table given the kVp that is used for the test. Note also that the reference (NCRP 99) is included. To the right is a table of lookup values that set the default behavior of the dosimeter.

has allowed us to successfully persuade vendors that a particular device is not performing at par, because we can easily see its siblings are doing better. The usual vendor response of, "It meets our spec," is less convincing when confronted with such documentation.

For any new potential user, there are some caveats. The sheets that couple to an external dosimeter have only been tested with Radcal dosimeters and software. Some of the calculations (for example the mR/mAs linearity) look at the unit field in the spreadsheet (which may contain either an "mR" or an "R") to divide by the correct power often. Look back carefully and you will see that the unit is not an "R" but a space plus "R". The Excel macros depend on this, and if other dosimeter vendors use different unit labels, the calculation will produce an error. Because the authors have no access to other equipment, it is hoped that helpful feed-

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1 **Pass/Fail Thresholds (can be altered for different machines or regulatory limits)**

2 Refs: WAC 246-225

3 Section 1

4 A.

5 slit str Focal spot, NCRP 99 Focal Spot Recommendations

6 star str Focal spot, NCRP 99 Focal Spot Recommendations.

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9 B.

10 mR/mAs str min mR/mAs, AAPM 225 mR/mAs guidelines

11 lin str mAs linearity, WAC 246-225-040 (10)

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13 C.

14 limit 10

15 str kV accuracy, WAC 246-225-040 (11)

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17 D.

18 str HVL, WAC 246-225-040 (5a).

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22 E.

23 limit 0.1

24 str 10% Average

25 str Exposure reproduc. WAC 246-225-090 (1)

26 str Timer reproduc. WAC 246-225-070 (4)

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33 Section 3A: Fixed the Pass/Fail showing "" if no data

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Fig 6. The web library for the Gnu-Medical Physics Tool site. Readers may reach this site and download any template for trials. The current “HOW TO” documentation is sparse but is being expanded as time permits.

quality control workbooks for all major devices in diagnostic imaging, built on a consistent design and methodology. It is our pleasure to offer these tools to the diagnostic physics community at large under the Gnu public license.⁸ Figure six shows the web site at which one may procure the spreadsheets, its web address is: <http://radweb.mcis.washington.edu/~sglanger>.

REFERENCES

1. Brooks KW, Trueblood JH, Kearfott KJ, et al: Automated analysis of the American College of Radiology mammographic accreditation phantom images. *Med Phys* 24:709-723, 1997

2. Gibson NM, Dudley NJ, Griffith K: A computerized quality control testing system for B-mode ultrasound. *Ultrasound Med Biol* 27: 1697-711, 2001

3. Li S, O'Dea TJ, Geise RA: Establishing a quality control program for an automated dosimetry system. *Med Phys* 26:1732-1737, 1999

4. American College of Radiology: Accreditation Programs. 1994. <http://www.acr.org/pubs/reports>

5. American Association of Physicists in Medicine: Reports. 1995. <http://www.fda.gov/cdrh/mammography/publications-rev.html>

6. Food and Drug Association Publications: Mammography Quality Standards Act. 1995

7. Tofani A: Automated procedures for radiation protection and quality controls in conventional diagnostic radiology. *Radiol Med* 96:394-398, 1998

8. Stallman R: Gnu's Not UNIX. 1984. <http://www.gnu.org>