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Software Bugs or Features?
Troubleshooting the Black Box: Part 2

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Prevalence of / Reliance upon “Black Box”

- BB has inputs and outputs but inner workings are unknown.
- Pros? Automation, Convenience, Already Built
- *Defers Responsibility*
- Additional appeal? “Processing Fluency” – information that is easy to digest tends to be more believable, positively received.

- *Doesn’t mean information is accurate / appropriate…*

Prevalence of/Reliance upon “Black Box”

- Cons?
- Quality of output (*and potentially input*) may be beyond your control, results difficult to validate.
- Difficult to modify/adapt if there are problems
- Just because something is commercially available may have little bearing on whether it is useful, accurate or has been vetted.

  Probably not subject to FDA approval or clearance (which may have little relevance to efficacy)

RDIM as example of BB software

Radiation Dose Index Monitoring software

- *Medical Physics Practice Guideline 6a:* Software that retrospectively collects radiation dose indices and other acquisition parameters … stores in a relational database along with patient demographics.
- Categorize by modality, study type, facility, demographic.
- Examples: Dose Monitor, Radimetrics, GE Dose Watch, Imalogix
- Increasingly popular in our dose conscient environment.

RDIM – Why do you want it?

- Appeal: Ostensibly able to collect and aggregate reported dose data across multiple modalities for large numbers of exams.
- Quality Control:
  - Practice review: identify outliers, analyze, standardize exam protocols & doses.
  - Dose Alerts – flag exams that exceed set thresholds for review.
  - Patient/physician dose requests
  - *Compliance: Calif. Requires CT dose indices to be included in Radiology reports (typically done through export of HL7 message into transcription software)*

The Reality …

- Unlikely RDIM implementation will be plug-and-play.
- Will likely need extensive configuration, validation, and troubleshooting…
- … by in-house experts familiar with the institution, the infrastructure, the imaging equipment, imaging modalities/capabilities, imaging protocols, dose & dose metrics, regulatory & accreditation requirements, data, databases, and data structure, I.T. & I.T. security
- E.g…. *The Physicist*
- **A mistake to go live without extensive testing.**

Troubleshooting - Questions you should be asking…

- What do you actually need it for?
- What are you actually getting?
- Is the “output” you’re getting appropriate and accurate?

Troubleshooting – Data scope/completeness

- RDIM doesn't know what it doesn't see/have. A query of dose for a given protocol, institution, or modality requires knowledge of all imaging devices that were configured, mined, and that data items are mapped appropriately, all for a desired date range.

- *Depending on type of RDIM input data available to be mined this may require considerable manual effort…*

Troubleshooting: Mined data formats/compatibility

Standardized, consistent

1) Radiation Dose Structured Report (RDSR): *DICOM standard for dose indices in structured format, minimal mapping problems.*
2) Modality Performed Procedure Steps (MPPS). *Info. sent to PACS/RIS: not dose specific, less structure, may not address metrics needed.*
3) Optical Character Recognition (OCR) *of screen capture (protocol page): Building and mapping challenges. No structure, many potential inputs.*

Manual effort and error prone, but flexible

4) Manual entry: *requires human interaction/effort. Inherent inaccuracies.*

- *AAPM Medical Physics Practice Guideline 6.a*
- *www.dicomstandard.org*

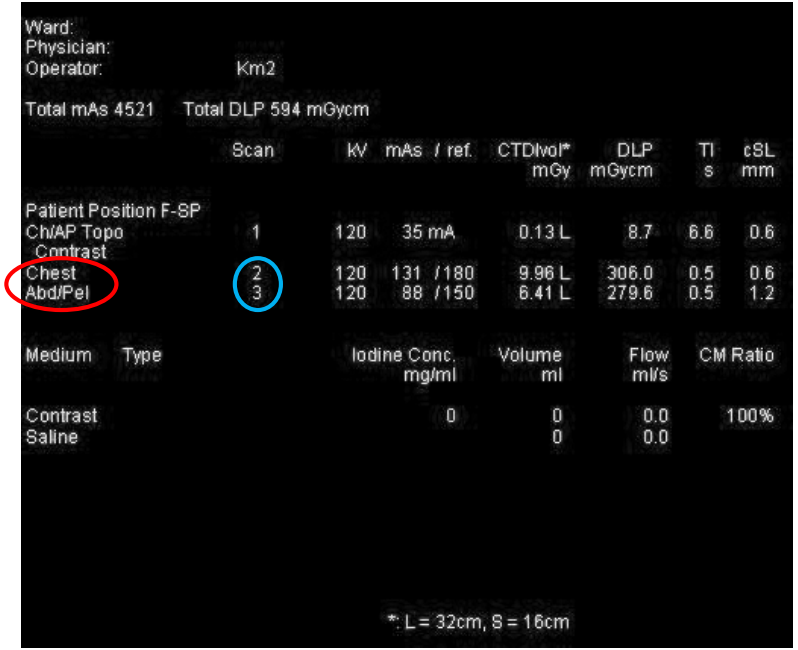
Troubleshooting: Mined data formats/compatibility

- RDSR easiest to implement but many (older) acquisition devices may not be compatible without expensive upgrades. Capability may be difficult to determine.
- May need to be configured on acquisition device by vendor.
- RDSR may not include desired elements (metrics for SSDE, WED) and difficult to mix/match data formats on a given system.
- Workflow → Failure to close study may result in no data sent

Troubleshooting: Dose metrics inappropriate/misleading

- Even “pass-through” metrics like CTDI may not be aggregated appropriately. A multi-phase CT study can have many exposure events (phases) each with their own CTDI & DLP.
- Dose information passed into the Radiology report can be extensive and longer than report itself. (common concern of Radiologist).
- Potential Result: Doses from different body regions added, or only a subset of exam exposure events are reported (highest dose phase?). Either makes determination of actual patient dose problematic.

Troubleshooting – mapping, labeling, errors



Ward:
Physician:
Operator: Km2

Total mAs 4521 Total DLP 594 mGycm

	Scan	kV	mAs / ref.	CTDIvol* mGy	DLP mGycm	TI s	cSL mm
Patient Position F-SP							
Ch/AP Topo	1	120	35 mA	0.13 L	8.7	6.6	0.6
Contrast							
Chest	2	120	131 /180	9.96 L	306.0	0.5	0.6
Abd/Pel	3	120	88 /150	6.41 L	279.6	0.5	1.2

Medium	Type	Iodine Conc. mg/ml	Volume ml	Flow ml/s	CM Ratio
Contrast		0	0	0.0	100%
Saline			0	0.0	

*: L = 32cm, S = 16cm

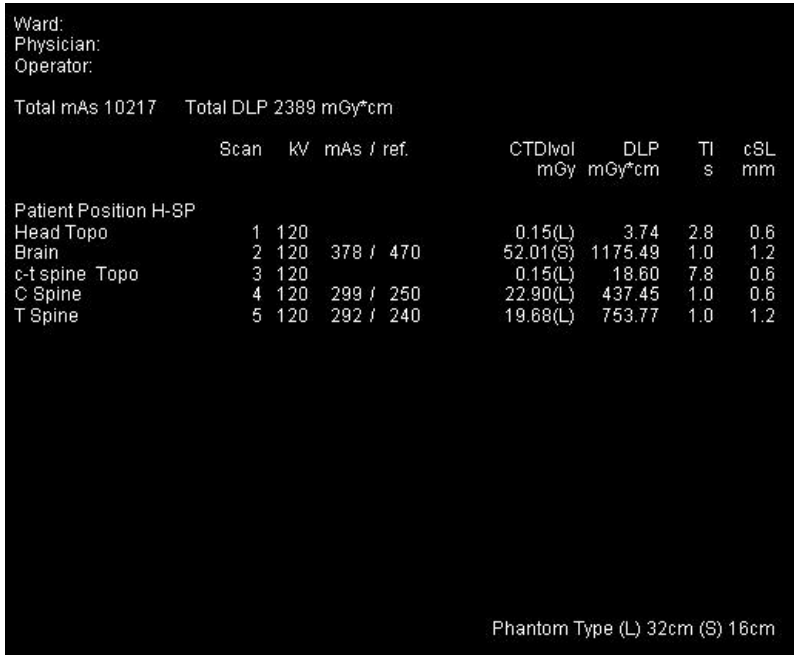
← Scanner protocol page (truth)

↓ Radiologist draft report

The patient received the following exposure event(s) during this study, and the dose reference values for each are as shown (CTDIvol in mGy, DLP in mGy-cm). Note that the values are not patient dose but numbers generated from scan acquisition factors based on 32 cm (L) and/or 16 cm (S) phantoms and may substantially under-estimate or over-estimate actual patient dose based on patient size and other factors.
CTDI(L): 6.4, DLP: 279.6; 1Chest_Abd_Pel,
CTDI(L): 10, DLP: 306; 1Chest_Abd_Pel,
CTDI(L): 9.6, DLP: 280.7; 1Chest_Abd_Pel;

- *Scan series names combined? Series names appropriate?*
  - *Series order/numbering?*
    - *Where did this series come from?*

Troubleshooting …



Ward:
Physician:
Operator:

Total mAs 10217 Total DLP 2389 mGy*cm

	Scan	kV	mAs / ref.	CTDIvol mGy	DLP mGy*cm	TI s	cSL mm
Patient Position H-SP							
Head Topo	1	120		0.15(L)	3.74	2.8	0.6
Brain	2	120	378 / 470	52.01(S)	1175.49	1.0	1.2
c-t spine Topo	3	120		0.15(L)	18.60	7.8	0.6
C Spine	4	120	299 / 250	22.90(L)	437.45	1.0	0.6
T Spine	5	120	292 / 240	19.68(L)	753.77	1.0	1.2

Phantom Type (L) 32cm (S) 16cm

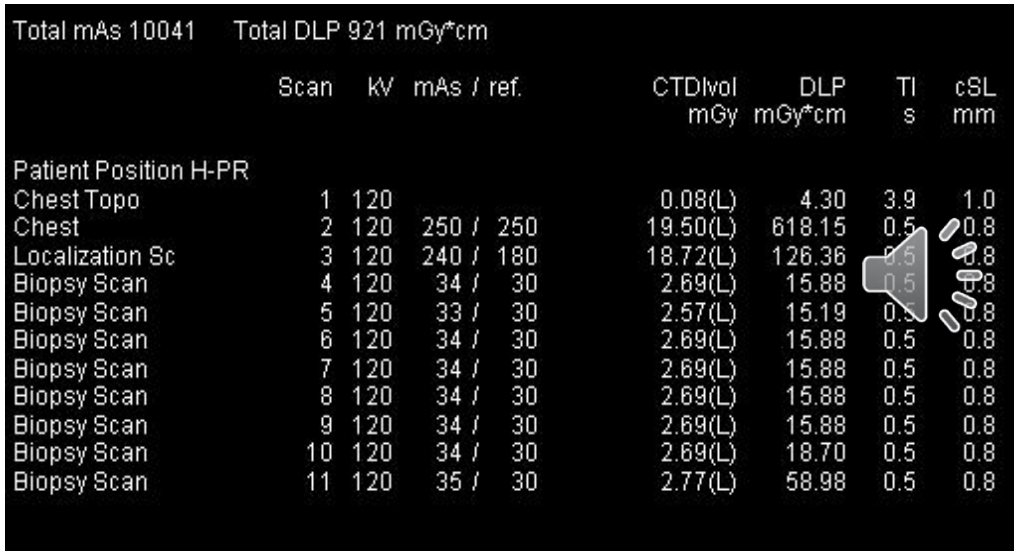
← Scanner protocol page (truth)

↓ Radiologist draft report

The patient received the following exposure event(s) during this study, and the dose reference values for each are as shown (CTDIvol in mGy, DLP in mGy-cm). Note that the values are not patient dose but numbers generated from scan acquisition factors based on 32 cm (L) and/or 16 cm (S) phantoms and may substantially under-estimate or over-estimate actual patient dose based on patient size and other factors. Phantom: BODY32/CTDIvol Mean: 20.95, mGy/DLP: 2389.05, mGy.cm.

- *One set of CT dose values reported for multiple series.*
- *What does "Mean" mean? (not the mean of the series…)*

Challenges of multiphase, interventional, studies



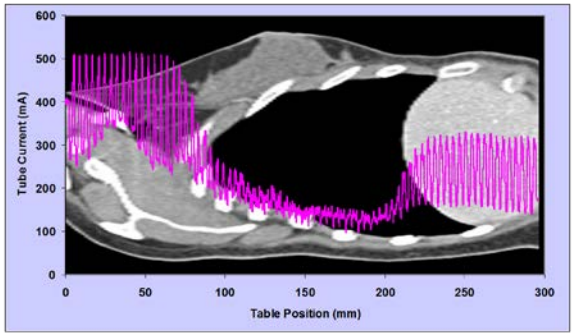
Total mAs 10041 Total DLP 921 mGy*cm

	Scan	kV	mAs / ref.	CTDIvol mGy	DLP mGy*cm	TI s	cSL mm
Patient Position H-PR							
Chest Topo	1	120		0.08(L)	4.30	3.9	1.0
Chest	2	120	250 / 250	19.50(L)	618.15	0.5	0.8
Localization Sc	3	120	240 / 180	18.72(L)	126.36	0.5	0.8
Biopsy Scan	4	120	34 / 30	2.69(L)	15.88	0.5	0.8
Biopsy Scan	5	120	33 / 30	2.57(L)	15.19	0.5	0.8
Biopsy Scan	6	120	34 / 30	2.69(L)	15.88	0.5	0.8
Biopsy Scan	7	120	34 / 30	2.69(L)	15.88	0.5	0.8
Biopsy Scan	8	120	34 / 30	2.69(L)	15.88	0.5	0.8
Biopsy Scan	9	120	34 / 30	2.69(L)	15.88	0.5	0.8
Biopsy Scan	10	120	34 / 30	2.69(L)	18.70	0.5	0.8
Biopsy Scan	11	120	35 / 30	2.77(L)	58.98	0.5	0.8

- Record / report max. values? (default)
- Record average?
- Sum values? How is location determined?
- … for a given body part? How does system determine?
- Defaults may not be appropriate. Who reviews/determines?

Troubleshooting: Less may be more

- Many data items available may be ill-defined or of limited relevance.
- CTDI effective min, max, mean, median? Age effective dose, weight effective dose, etc.? What do these metrics actually represent? Are they defined, labeled appropriately?
- Do mean CTDI values represent all phases of a study? Only the phases within a given body part? Or do they represent average of multiple slices within a single TCM scan where output varies?



Troubleshooting – Understand output metrics

RDIM may go beyond database / aggregator of imaging device dose metrics. Additional calculations may be provided that aren't needed, have limited relevance, and/or can't be validated.

- "Pass-through" metrics like CTDI, DLP, and Air Kerma originate from scanner or acquisition device and if aggregated and analyzed properly provide useful practice feedback.
- Empirical values that are explicitly defined (phantoms) and can be verified/validated
- *However, CTDI, DLP, AK do not account for patient size, are NOT patient doses…*

Troubleshooting – Less may be more…

Additional marketed features like Peak Skin Dose or Effective Dose may have appeal. However…

- These are calculated - not measured - values dependent on model, methods, and assumptions used (ED from different RDIM systems can vary substantially, PSD requires beam entrance location and extent, etc.)
- Not easily validated, granularity gives impression of unwarranted degree of accuracy.
- ED not recommended for cumulative patient dose, and even dose from a given exam should be considered/validated via a QMP.

The problem with Effective Dose …

- Based on standardized human models using committee determined population derived tissue weighting factors, does not accurately represent dose or risk to specific individuals
- Doesn't predict future cancer risk
- Intended for prospective planning, risk estimates for populations.

- *(Nevertheless, frequently used for individual risk estimates and comparison shopping by patients/physicians. Input for risk calculators. Potentially useful with appropriate caveats).*

- *ICRP 103, 2007 Recommendations of the International Commission on Radiological Protection*
- *Fisher/Fahey - Appropriate use of Effective Dose in Radiation Protection and Risk Assessment*

Troubleshooting: Protocol standardization

- Effective analyses / comparisons of dose requires defining and standardizing scan protocols and naming conventions …
- …considering anatomy, lexicons, departments/sections, scanner specific capabilities, procedure type, procedure complexity/scan phases, procedure groupings, etc.
- Elements for comparison? A routine CT head: with/without contrast? CTA? TCM, on what type of machine?
- A chest abdomen pelvis grouped under chest? CTDI summed?

Recommended approach to troubleshooting …

Define expectations (beforehand)…

- Purchase Specs: First step is to define what you want, or at least your immediate priorities.
- Educate yourself on the BB input you're actually able to provide (RDSR, OCR, etc.)

- For RDIM specifications, *AAPM medical physics practice guideline 6.a* is great place to start defining your needs…

Review what you're getting …

- Are all relevant acquisition devices being represented?
- Are the metrics you wanted what you're getting?
- Are they complete? (system doesn't know what it's missing, many acquisition devices/data elements may not be compatible).
- Are the data elements mapped properly? Are they being aggregated (summed, presented) properly?

Validate what you're getting …

- Can you confirm the BB output metrics?
- If pass-through data, do you have tools/data to compare against?
  - Dose protocol pages, PACS, DICOM images, measurements.
- If analytic or calculated output metrics are available (ED), consider …
  - How will they be used?
  - How might they be validated?
  - How accurate are they, how accurate do they need to be?

Challenges

- What control do you have over the process?
  - Purchasing? Specifications? Implementation? Approval?
  - Demo capabilities = possibilities ≠ practical realities
- I.T. will likely be a necessary partner. May have little understanding of the tool, the data elements, or how to validate … much less troubleshoot. Meeting their requirements may not meet yours.
- Test drive before you buy and do beta testing before go-live!

Final thoughts on troubleshooting BB…

- "Shallow men believe in luck or in circumstance. Strong men believe in cause and effect." — *Ralph Waldo Emerson*
- *Genchi Genbutsu* (Go and see for yourself): Toyota Philosophy – the best way to make sure a production line is working at maximum efficiency is to go and see if for yourself.
- The purchased black box does not absolve institution of its responsibilities. Caveat Emptor!
- *Physicist role: Owner or consultant? Occupational hazard: physicists question, are best prepared to understand subtleties & technical details, consummate troubleshooters!*