RSNA 2011 – ID 11009915 (Session: THU 12/1, 12:45-1:15p)

Initiation of Fluoroscopy Time and Dose Data Mining and Surveillance for Continuous Quality Assurance Improvement Process

David A. Zamora, M.S.
Kalpana M. Kanal, Ph.D., DABR
Renée L. Dickinson, M.S.
Brent K. Stewart, Ph.D., DABMP

University of Washington Medical Center
Department of Radiology
Diagnostic Physics Section
Seattle, WA 98195

Acknowledgements

- Clinical and Administrative Support
  - William Shuman, MD
  - Charles Rohrmann, MD
  - Leigh Ann Russell, Diagnostic Imaging Supervisor
  - Ghrmai Mebrahtu, Imaging/QC Technologist
  - Allen Patten, Imaging Technologist
  - Other UWMC Radiology Faculty and Staff
- Information Technology
  - Andy Strickland
  - Kristal Hoagland
  - UWMC Radiology IT
- Clinical Engineering
  - Dennis Conroy
  - Frank Welsh

Outline

- Introduction
  - Necessity of Tracking Dose Metrics in Fluoroscopy
  - Possible Dose Metrics and Their Strengths/Weaknesses
  - Problem and Project Aims
- Methods and Materials
  - Primary Workflow
  - Preparatory Work: Unification of Dose Metric Values
  - Radiology Information System (RIS) Implementation
  - Data Fidelity
  - Numerical Analysis Process
- Results
  - Presentation States
  - Clinical Feedback Loop
- Discussion and Conclusion
  - Successes and Challenges
  - Avenues for Future Work

INTRODUCTION

Introduction

Necessity of Tracking Dose

- Potential for radiation injury in fluoroscopic procedures, typically to the skin due to the primary radiation:[1, 2]
  - Erythema (transient/prolonged)
  - Epilation (temporary/permanent)
  - Or more severely: ulceration / desquamation / necrosis
- More prominent coverage in news[3] of medical radiation events, higher patient awareness leads to need for dose information
- Establishment of baseline 'normal' values of displayed dose is prudent in clinical practice
- Identification of possible *atypically high* doses for a given procedure offers the opportunity to improve individual practice or system processes

1. S. Balter, J. W. Hopewell, D. L. Miller, L. K. Wagner and M. J. Zelefsky, "Fluoroscopically guided interventional procedures: a review of radiation effects on patients' skin and hair," Radiology **254**, 326-341.
2. Wagner, LK, Eifel PJ, Geise RA. Potential Biological effects following high x-ray dose interventional procedures. J Vasc Interv Radiol 1994;5:71-84.
3. Bogdanich, W., "After Stroke Scans, Patients Face Serious Health Risks," The New York Times, 31 Jul 2010.

Introduction

Potential Dose Metrics

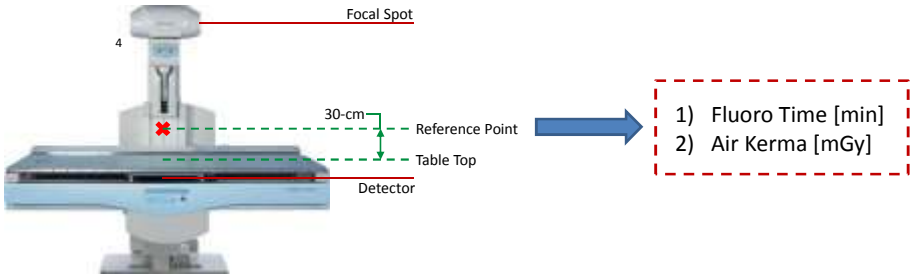
- <u>Fluoroscopy Time</u> (in sec or min)
  - Active x-ray beam-on time during the procedure
    - \+ Easy to measure
    - \+ Easy to understand
    - \- Poor correlation to actual dose (often)
    - \- No account for radiographic technique
- <u>Air Kerma</u> (AK, in mGy)
  - Calculated air kerma to a reference point
    - \+ Accounts for utilized radiographic technique parameters
    - \+ Use to estimate patient skin dose
    - \- Lacks geometric information, such as field size utilized in acquisition
- <u>Dose Area Product</u> (DAP, in mGy-cm^2)
  - Product of calculated/measured AK and field area at a reference point
    - \+ Accounts for utilized radiographic technique parameters
    - \+ Use to estimate patient skin dose and effective dose
    - \- Field size often not documented

Introduction

Potential Dose Metrics

Systems that provide an output of dose (Air Kerma or DAP) define a 'reference point' in air to which the displayed dose value is calculated.

The sample fluoroscopic system below defines the AK dose display reference point as 30-cm above the table top.



RSNA 2011

4. Shimadzu Corporation, <http://www.shimadzu.com/products/medical/fluoro/oh80jt0000002plg.html>, accessed October 11, 2011.

7

Introduction

Problem and Project Aims

PROBLEM

- The manner in which dose metrics are displayed varies widely on fluoroscopic equipment
- There exists a disconnect between the individual vendor-provided dose metric and the ability to compile population statistics for a given procedure and/or piece of equipment

PROJECT AIMS

- For a set of fluoroscopic equipment (excluding angiographic systems, which are monitored at our institution by another process), we aim to:
  1. Develop a QA methodology to collect and evaluate fluoroscopy time and dose information from procedures performed at our institution
  2. Generate baseline 'normal' dose metrics for fluoroscopic procedures
  3. Implement a system of clinical feedback and optimization by reviewing longitudinal changes in time/dose metrics

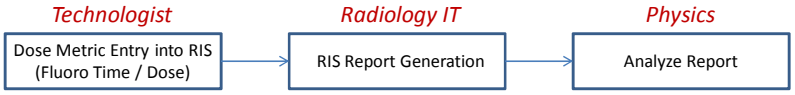
RSNA 2011

8

METHODS AND MATERIALS

Methods

Primary Workflow



In this project, the most direct implementation was to have the technologist manually enter the dose metric into our institution's Radiology Information System (RIS)

Once numerical values are in the RIS, our IT specialists can generate a report containing:

- Patient Name
- Medical Record Number
- Accession Number
- Procedure Type
- Procedure Date and Time
- Equipment Type/Name
- Fluoro Dose Metric (Time and AK)

From this raw data output, the Physics section can classify and analyze the data as desired by the clinic

RSNA 2011 10

Methods — *Preparatory Work*

PROBLEM: Each piece of equipment has its own way of displaying the dose metric!

- Metric Class: Time | AK | DAP | Nothing?
- Displayed Units: sec | min | mGy | cGy | uGy | mGy-cm^2 | mGy-m^2…

SOLUTIONS and VERIFICATIONS:

- Document the current state of dose display on the equipment of interest
  - Dose Display / Dose Reference Point / Software Version
- Define the *ideal* dose display and then unify the dose metric display on your equipment
  - Changing units and dose display *may require* modification of system settings and possible system software upgrade
  - Again, document any changes that were made for future reference
- Verify proper calibration/accuracy of dose display – displayed value should correspond to actual exposure/dose measurements with an ion chamber at the equipment dose reference point – suggest doing so at annual physics survey

Methods — *RIS Implementation*

BENEFITS OF USING RIS

- It allows us access to pertinent study information for each patient/study that is performed
- The database allows for customizable report output, per your needs

RIS IMPLEMENTATION

- Entry Field
  - Accepts numerical value?
  - Sufficient number of digits?
  - Accepts decimal?
  - Available for usage?
- Staff Training
  - Where do I find dose metrics (dose rpt)?
  - What dose/time value (cumulative, units)?
  - What field do I populate in RIS?
  - How do I note the equipment used?
  - Send dose report to PACS as a backup
- Report Generation
  - What fields are of interest?
  - How frequently do we generate report?
  - Who gets the report?

Methods

RIS Implementation

- Our current version of RIS (*GE Centricity RIS-IC 10.7.0.407 UP6.4)* does not have a dedicated entry field for a dose metric (AK or DAP)
- Therefore, we identified an entry field that would:
  - Accept numerical data
  - Accept a sufficient number of digits for range of AK values we encounter
  - Not affect other clinical RIS usage
  - Be available during patient RIS study completion

For Air Kerma (AK), we selected the unused mAs field to store the numerical value

Methods

Data Fidelity

DATA VERIFICATION PROCESS

- There are many stages between the procedure and the metrics in the RIS report
- *Each step* presents the possibility of data corruption, it is important to understand how/why
- It is advisable to follow a test patient from start to finish for each piece of equipment

Equipment Display	→	Manual RIS Entry	→	Database Storage	→	RIS Report Query	→	Crystal Report Output
Calibrated?		Mis-entry?		Factors applied?		Correct references?		Missing data?

Sample Practical Issues We Have Encountered

- In our RIS, the 'Fluoro Time' field has no units [min or sec] associated with it. The numerical value entered in the RIS interface is *displayed* consistently, but the stored database value includes a multiplicative factor of 60 (i.e. it assumes entry in minutes, storage in seconds). The numerical value in the database propagates to the generated report.

Methods

Analysis Process

Fluoro Exams with Fluoro Time

MRN	Accession	Date	Proc_cod	Proc_desc	AK	Time	Equip_code	Equip_desc
----------	----------	----------	XESOV	XR VIDEO ESOPHAGRAM	54.50	162	UMRAD9	REMOTE DIGITAL FLUORO
----------	----------	----------	XFLUO1	XR FLUORO UP TO 1 HRS	56.00	336	PVCAR4	SURGERY PAVILLION C-ARM 4
----------	----------	----------	XUGIK	XR UPPER GI W KUB	70.40	90	UMRAD9	REMOTE DIGITAL FLUORO
----------	----------	----------	XESOC	XR ESOPHAGRAM COMPLETE	45.40	84	UMRAD9	REMOTE DIGITAL FLUORO
----------	----------	----------	XFLUO1	XR FLUORO UP TO 1 HRS	2.70	1,596	ORCAR6A	OR C-ARM 6A
----------	----------	----------	XESOV	XR VIDEO ESOPHAGRAM	18.80	96	UMRAD9	REMOTE DIGITAL FLUORO
----------	----------	----------	XF[illegible]	XR FLUORO UP TO 1 HRS	2	[illegible]	[illegible]AR1	SU[illegible]PAVILLION C-ARM 1
----------	----------	----------	XFLUO1	XR FLUORO UP TO 1 HRS	1	[illegible]	[illegible]AR2	SU[illegible]PAVILLION C-ARM 2
----------	----------	----------	XFLUO1	XR FLUORO UP TO 1 HRS	2.70	2,088	ORCAR6A	OR C-ARM 6A
----------	----------	----------	XURORE	XR UROGRAM RETROGRADE	12.70	2,370	PVCAR1	SURGERY PAVILLION C-ARM 1
----------	----------	----------	XURERC	XR URETHROCYSTOGRAM RET COMP	26.60	18	UMRAD9	REMOTE DIGITAL FLUORO
----------	----------	----------	XFLUO1	XR FLUORO UP TO 1 HRS	101.20	8,976	ORCAR1	OR C-ARM 1A
----------	----------	----------	XANK2	XR ANKLE 2 VIEWS	1.00	0	ORCAR6A	OR C-ARM 6A

- Our group established our ideal dose metrics as:
  - Fluoro Time [sec]
  - Air Kerma [mGy]
- However, our ideal dose metric *units* were not universally attainable on all equipment, so it is important to maintain proper documentation
- With the data from RIS, we developed an automated analysis program (MATLAB R2011a) that classifies and generates statistics for the data

Methods

Analysis Process

A CATEGORIZATION

Parse Study Date: - Year, define Quarter (Q1/Q2/Q3/Q4)
Categorize Equipment: - CARM / DIGITAL / RF / RF2 / OTHER / PAIN

For input dataset, determine **UNIQUE** instances of year, quarter, equipment class, procedure type…

B ANALYSIS – TIME and AIR KERMA

For a given year, quarter, equipment class, procedure type:

Strip '0' Entries or Non-entries, track dose metric input compliance
Calculate Basic Statistics (original)

↓

Calculate z-score, exclude studies over some statistical metric (z-score > 5)
Calculate Basic Statistics (exclusions)

↓

Limit dataset to studies within μ + 2σ for a given distribution
Calculate Basic Statistics (adjusted)

OUTPUT

- # Zero Entries (compliance)
- Original μ [mean], σ [SD], μ+2σ, median, first/third quartile, max/min
- Statistical Outliers (Excl)
- Post-exclusion μ, σ, μ+2σ, median, first/third quartile, max/min
- Atypical Administration† (Adj)
- Adjusted μ, σ, μ+2σ, median, first/third quartile, max/min
- Graphing
- Trending Analysis

† defining metrics by which to classify a study as 'atypical' is in process

RESULTS

Results

Presentation States

- Using the automated analysis program, we generate these statistics for a given equipment class, year/quarter, and procedure type…

Equipment Class	Year	Quarter	Procedure	n_zeros	count	mean	SD	mu+2sig	min	25th perc	median	75th perc	max
REMOTE FLUORO	2011	Q3	ADRAIN	0	1	61	0	61	61	61	61	61	61
REMOTE FLUORO	2011	Q3	XBESC	0	2	55	30	115	33	33	55	76	76
REMOTE FLUORO	2011	Q3	XCHOPO	0	1	108	0	108	108	108	108	108	108
REMOTE FLUORO	2011	Q2	XESOC	0	53	64	42	148	1	33	54	87	174
REMOTE FLUORO	2011	Q3	XESOC	0	84	56	34	123	5	34	54	75	167
REMOTE FLUORO	2011	Q2	XESOV	0	96	36	35	105	1	11	21	47	169
REMOTE FLUORO	2011	Q3	XESOV	0	114	39	36	111	3	13	26	54	172
REMOTE FLUORO	2011	Q3	XFLCHE	0	1	9	0	9	9	9	9	9	9
REMOTE FLUORO	2011	Q3	XGITUB	0	2	6	7	20	1	1	6	11	11
REMOTE FLUORO	2011	Q3	XMYEES	0	1	54	0	54	54	54	54	54	54
REMOTE FLUORO	2011	Q3	XMYELS	0	1	19	0	19	19	19	19	19	19
REMOTE FLUORO	2011	Q2	XSBFT	0	2	98	99	297	28	28	98	168	168
REMOTE FLUORO	2011	Q3	XSBFT	0	5	78	94	265	13	22	28	126	237
REMOTE FLUORO	2011	Q2	XSNIFF	0	7	49	17	83	27	37	45	63	74
REMOTE FLUORO	2011	Q3	XSNIFF	0	8	50	20	90	20	36	50	65	79
REMOTE FLUORO	2011	Q2	XSPLPU	0	1	81	0	81	81	81	81	81	81
REMOTE FLUORO	2011	Q3	XUGI	0	3	102	61	224	44	57	96	148	166
REMOTE FLUORO	2011	Q1	XUGIAK	0	1	90	0	90	90	90	90	90	90
REMOTE FLUORO	2011	Q2	XUGIAK	0	22	160	80	319	51	104	152	211	361
REMOTE FLUORO	2011	Q3	XUGIAK	0	25	101	59	219	34	53	76	135	241
REMOTE FLUORO	2011	Q2	XUGIAS	0	2	689	216	1121	536	536	689	842	842
REMOTE FLUORO	2011	Q3	XUGIAS	0	2	62	7	76	57	57	62	67	67
REMOTE FLUORO	2011	Q2	XUGIK	0	116	101	54	208	14	63	92	125	270
REMOTE FLUORO	2011	Q3	XUGIK	0	130	97	53	203	3	56	85	125	288
REMOTE FLUORO	2011	Q2	XUGISB	0	6	78	38	154	43	54	69	81	151
REMOTE FLUORO	2011	Q3	XUGISB	0	18	127	91	309	8	39	117	188	293
REMOTE FLUORO	2011	Q3	XURERC	0	1	27	0	27	27	27	27	27	27
REMOTE FLUORO	2011	Q3	XUREVC	0	1	4	0	4	4	4	4	4	4

We can identify those procedures that are high frequency and/or high dose to further analyze with the clinical faculty/staff

Results

Presentation States

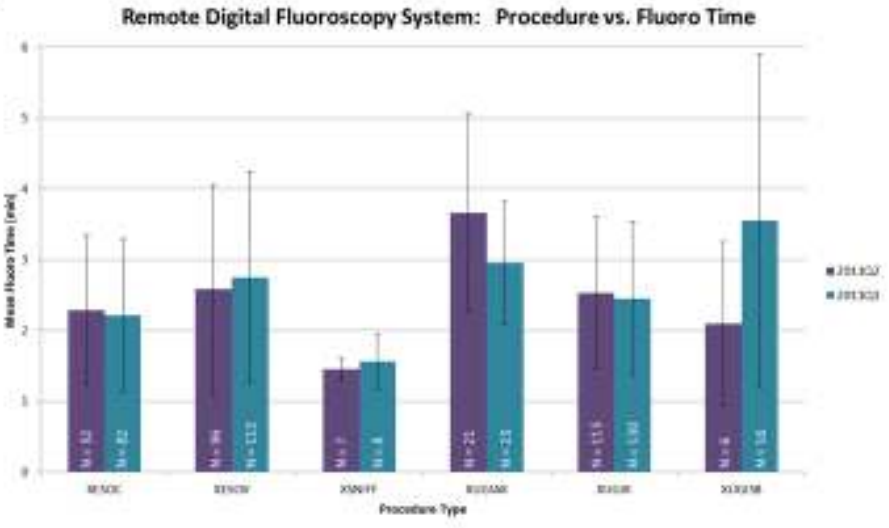
- Once numerical results have been generated, the question becomes:

  How can we effectively present this to the clinic?

- We have two primary presentation states:
  1. Column Graph Longitudinal Trend of Average Dose Metric Values
  2. Box-and-whisker plot of Dose Metric Values

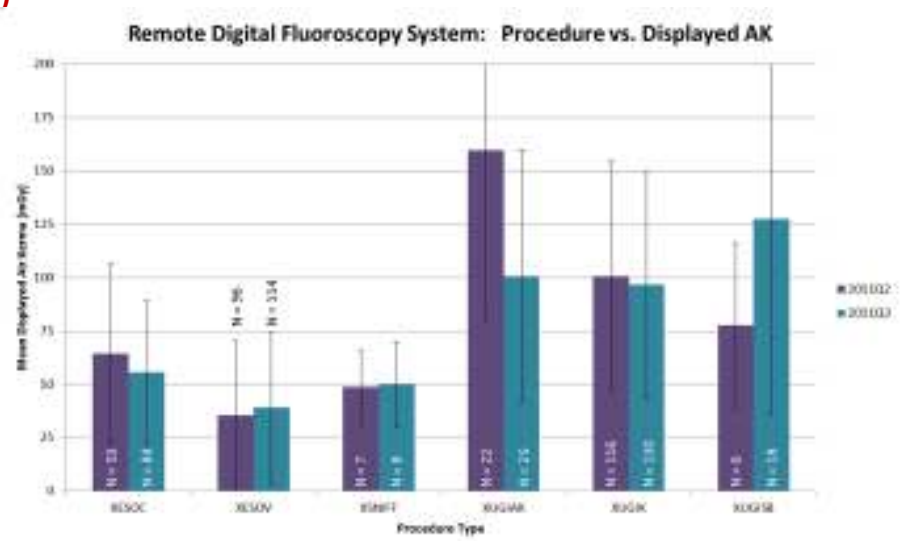
- The following 4 sample slides exhibit quarterly procedural data for a sample remote digital fluoroscopy system:
  - A. Longitudinal Column Graph, Mean Procedure Time, Error Bar = 1SD
  - B. Longitudinal Column Graph, Mean Displayed AK, Error Bar = 1SD
  - C. Single Quarter Snapshot Box-Plot of Displayed AK
  - D. Longitudinal Box-Plot of Displayed AK

A)



XESOC – ESOPHAGRAM COMPLETE
XESOV – VIDEO ESOPHAGRAM
XSNIFF – SNIFF TEST DIAPHRAGM
XUGIAK – UPPER GI w/ AIR w/ KUB
XUGIK – UPPER GI w/ KUB
XUGISB – UPPER GI w/ SMALL BOWEL

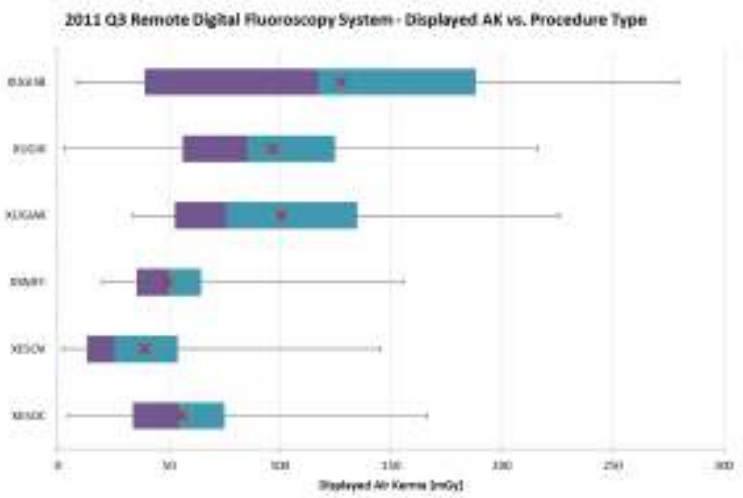
B)



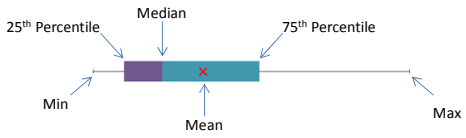
XESOC – ESOPHAGRAM COMPLETE
XESOV – VIDEO ESOPHAGRAM
XSNIFF – SNIFF TEST DIAPHRAGM
XUGIAK – UPPER GI w/ AIR w/ KUB
XUGIK – UPPER GI w/ KUB
XUGISB – UPPER GI w/ SMALL BOWEL

RSNA 2011

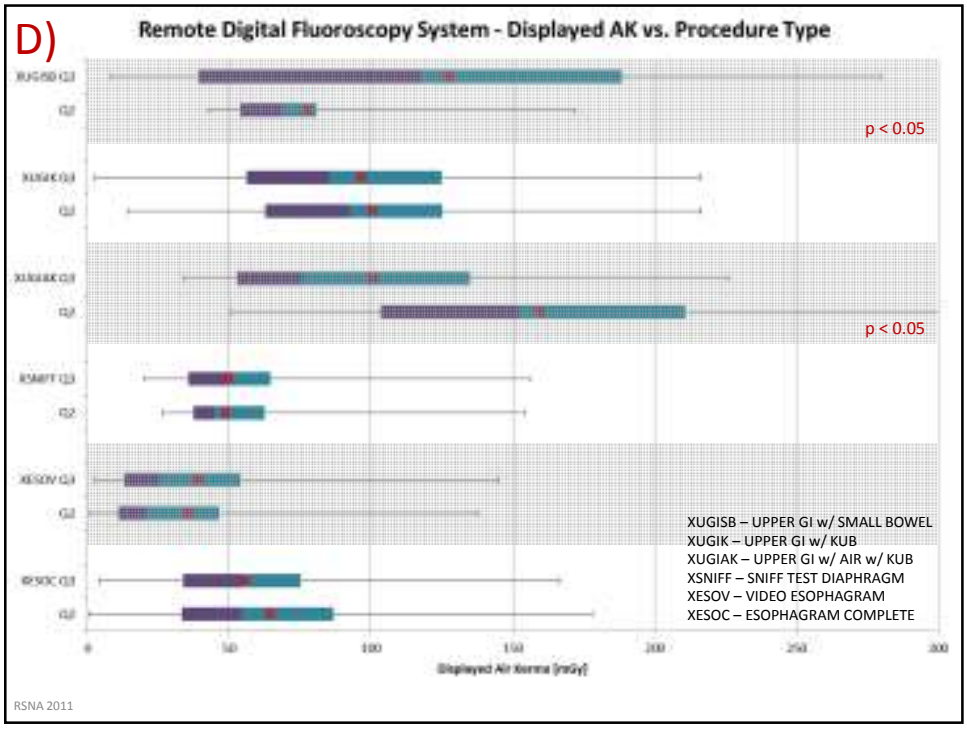
C)

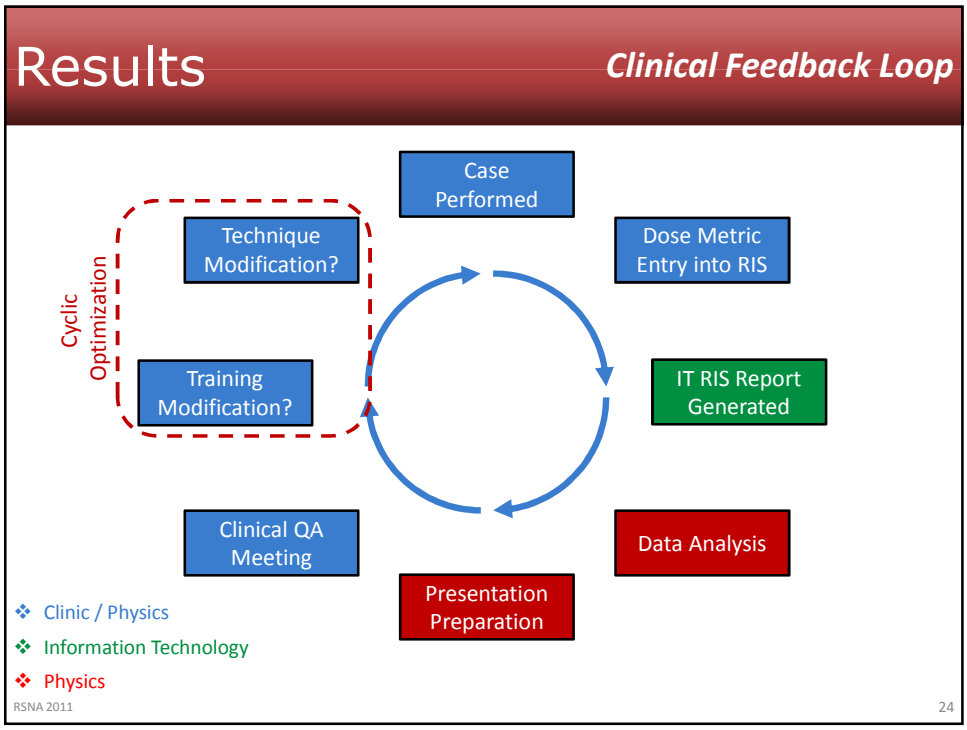


XUGISB – UPPER GI w/ SMALL BOWEL
XUGIK – UPPER GI w/ KUB
XUGIAK – UPPER GI w/ AIR w/ KUB
XSNIFF – SNIFF TEST DIAPHRAGM
XESOV – VIDEO ESOPHAGRAM
XESOC – ESOPHAGRAM COMPLETE



RSNA 2011


D)
Remote Digital Fluoroscopy System - Displayed AK vs. Procedure Type
p < 0.05
p < 0.05
XUGISB – UPPER GI w/ SMALL BOWEL
XUGIK – UPPER GI w/ KUB
XUGIAK – UPPER GI w/ AIR w/ KUB
XSNIFF – SNIFF TEST DIAPHRAGM
XESOV – VIDEO ESOPHAGRAM
XESOC – ESOPHAGRAM COMPLETE
RSNA 2011


Results
Clinical Feedback Loop
Case Performed
Dose Metric Entry into RIS
IT RIS Report Generated
Data Analysis
Presentation Preparation
Clinical QA Meeting
Training Modification?
Technique Modification?
Cyclic Optimization
Clinic / Physics
Information Technology
Physics
RSNA 2011
24

DISCUSSION AND CONCLUSION

Discussion

Successes and Challenges

- The processes implemented in this project have allowed our institution to examine previously unavailable metrics
- Not only have we been able to generate procedural statistics, but the level of awareness on radiation dose has increased, evidenced by an increase in requests for dose monitoring by our group

- HOWEVER, challenges remain – the quality of analysis we can generate is limited by the quality of the data provided:
  - For certain pieces of equipment, we are unable to clearly establish the type of procedure that was performed – issues such as this are systemic in nature, and will require additional clinical and RIS support to resolve
  - The current workflow relies on a manual entry process, automation would improve data fidelity – issues such as this would require increased interaction between equipment vendors and end-users

Discussion

Successes and Challenges

- Insofar as the manner in which this data is presented to the clinic, we have learned a few things:
  - Box-and-whisker plots contain much more useful information than simply tracking changes in the mean value
  - Availability of the number of procedures performed in a given period is pertinent and should be provided
- On future iterations, as we generate more data:
  - All data will be presented as box-and-whisker
  - Longitudinal studies will show three consecutive quarters of data
  - We will better incorporate the number of procedures performed
  - We will provide a listing of statistical outliers for further investigation
  - We will provide a listing of atypically high (statistical metric under deliberation) administrations for further investigation

Discussion

Successes and Challenges

- The compilation of dose information is limited, in some ways, by the information made available to the user by the vendors
- Some products/abilities that would be useful in the increasingly important issue of radiation dose include:

Radiographic Equipment
- Transparent access to technical docs
- Increased flexibility in dose metric displayed units
- Flagging notification value thresholds
- Usage of DICOM structured dose reports
- Line-item documentation of acquisition parameters (technique / geometry)
- Development of geometric models to estimate spatial dose deposition

RIS Administration Interface
- Increased flexibility in user-defined fields
- Transparency in the usage of numerical units of dose/technique entry
- Development of standardized dose/technique metrics for each imaging modality
- Improved response time to changing clinical technology

Discussion

Future Work

- Develop a reasonable method to convert displayed Air Kerma (AK) to Entrance-to-Skin Dose (ESD) for varied equipment
  - Required geometric assumptions (inverse square correction), backscatter factors, table attenuation (where applicable), etc…
- Attempt to better-define the procedure type
  - An improved ability to categorize procedures into more specific categories will allow better results – this may be connected to the clinical workflow and/or the flexibility of our current RIS implementation
- Further develop our ability to assess 'statistical significance' when analyzing data trends
  - Current Quarter vs. Prior Quarter?
  - Current Quarter vs. Population Average?
- Determine the best way to interpret changes in data results
  - Correlate shifts in quarterly data to changing techniques/training

Conclusion

- While the progression of quality improvement continues to develop, the generation of a process for gathering fluoroscopy dose metrics has allowed us the opportunity to:
  1. Develop a QA methodology to collect and evaluate fluoroscopy time and dose information from procedures performed at our institution
  2. Generate baseline 'normal' dose metrics for fluoroscopic procedures
  3. Implement a system of clinical feedback and optimization by reviewing longitudinal changes in time/dose metrics

THANK YOU

Comments/Suggestions:

University of Washington
Department of Radiology
ATTN: David Zamora
1959 NE Pacific Street
Box 357987
Seattle, WA 98195-7987

dzamora@uw.edu