AAPM 2018 JUL 29 - AUG 2 BEYOND THE FUTURE! 60th ANNUAL MEETING & EXHIBITION | NASHVILLE, TN

UNIVERSITY OF VIRGINIA HEALTH SYSTEM

Acceptance and Acceptability Testing of Modern Fluoroscopy Equipment - Dosimetry

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Disclosures:

- Member, Bayer Healthcare Global Advisory Board

Brief Outline

1. Post Installation IT Configuration
2. KAP verification and testing
3. System maximum output/Regulatory testing
4. Programming system for use
5. Patient exposure measurements/testing
6. RDIM setup and use
7. QC activities to ensure Acceptability

Task Group 272-Comprehensive Acceptance Testing and Evaluation of Fluoroscopy Imaging Systems

Charge

To define testing procedures for fluoroscopic imaging systems including conventional, mobile C-arm, and interventional/angiography systems, thereby establishing a comprehensive acceptance test procedure for practicing medical physicists, incorporating:

(a) Regulatory tests and measurements including procedures described in the NEMA standard XR 27-2013, "X-ray Equipment for Interventional Procedures User Quality Control Mode" and

(b) Image quality assessment accounting for new technological advancements in fluoroscopy equipment design.

Work is in progress…stay tuned.

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IT/Connectivity during acceptance

Although the focus of this talk is geared to dosimetry and acceptance of a new unit used for Fluoroscopically Guided Interventions (FGI's), the interconnectivity of that unit cannot be overlooked due to its importance in understanding how the unit is used.

Questions to Ask as you Acceptance Test a new Fluoroscope:

- Reported dose metrics in PACS or RDIM?
- Exam technical parameters correct in PACS or RDIM?
- Study nomenclature correct in PACS or RDIM?
- Image quality in PACS adequate/matching?
- Route of sending data to your RDIM? Direct or via PACS?
- What data can be sent to RDIM: Radiation Dose Structured Report or RDSR, "dose sheets", DICOM images?
- *Work with the vendor to get the maximum utilization out of your data*

Station Names such as "IR", or "CathLab" are not helpful. Use descriptors that aid in identification later in upstream systems

Stay tuned: AAPM Task Group Report 248 (TG-248)-Interoperability Assessment for the Commissioning of Medical Imaging Systems (in revision)

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NEMA XR-27 Standard

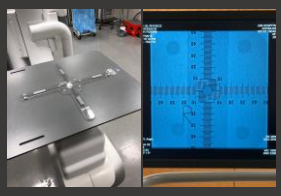
- X-ray Equipment for Interventional Procedures User Quality Control Mode
- Means provided for manual measurement of; HVL, Dose reproducibility, mA linearity, kVp, mA and pulse width accuracy, CAK and DAP accuracy, and X-ray tube output measurement
- Manual controls for: kV, mA, ms, spectral filter, FS size
- Units are **currently** shipping from vendors with XR-27 installed
- Set up passwords/accounts during acceptance

KAP Meter testing

- Now required annually by The Joint Commission
- Consult AAPM Task Group-190 Report
- Goals 1) determine accuracy, 2) determine and record offset to be useful in patient dose calculations

- **Acceptance:** for fluoroscopes manufactured after 2006, installed or indicating $K_{a,r}$ and $K_{a,r}$ rate operating without error greater than ± 35%.
- **Acceptability:** we like ± 10%

KAP Meter testing- field size determination



Set 10x10cm FOV

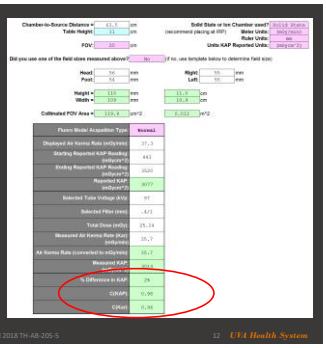
measure actual FOV on alternative CR/DR device

KAP Meter testing

- We use SS detector in air @ IRP
- Scatter free conditions
- Enough Cu to drive fluoroscope to 90-100keV
- Fluoro for ~ 25-50 mGy on meter – record results

KAP Meter testing

- For KAP, compare to ACTUAL field of view with separate receptor
- Determine C_{KAP} and $C_{Ka,r}$
- Perform for Fluoro & Acquisition
- Adjustments can and should be made if errors are out of tolerance or unusable



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The Joint Commission Sayeth…

Standard EC.02.04.03

34. For hospitals that provide fluoroscopic services: At least annually, a diagnostic medical physicist conducts a performance evaluation of fluoroscopic imaging equipment. The evaluation results, along with recommendations for correcting any problems identified, are documented. The evaluation includes an assessment of the following:
….
- **Maximum exposure rate in all imaging modes**
- **Displayed air-kerma rate and cumulative-air kerma accuracy (when applicable)**

- Starting in January 2019, we will need to test these items
- ….for all levels, at the maximum frame rate
- *Testing in ALL modes may impact length of testing*

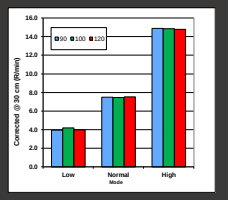
Maximum Output – Fluoroscopy

- Need to satisfy 88mGy/min (10 R/min) for non-HLC Fluoro
- Need to satisfy 176mGy/min (20 R/min) for HLC Fluoro
- FDA measurement point, 30 cm from receptor
- We check min, 100 cm, and max SIDs
- If not in Service Mode- ensure a program is capable of going over 88mGy/min before indicating device is not capable
- "20R", "High Contrast" are examples of programs to look for that may achieve these values
- **Acceptance:** <88 mGy/min (non HLC), <176 mGy/min HLC.
- **Acceptability:** for HLC Fluoro, <158 mGy/min (for margin of safety

Maximum Output – Fluoroscopy

- Measurements should be made in air
- Scatter free conditions
- Highest magnification

Mode	HLC or Boost	SID	Fluoro Type	kVp	mA	Measured Exposure Rate R/min	Corrected Exposure Rate @ 30 cm (Angio) OR Table Top (Gen'Fluoro) R/min	Corrected Air Kerma Rate mGy/min	Pass/ Fail?
Low	N	90	3ppa Fluoro	125	240.0	3.3	3.9	34.4	PASS
Normal	N		7.5ppa Fluoro	125	241.0	6.2	7.5	65.7	PASS
High	Y		7.5ppa Fluoro	125	244.0	12.3	14.9	130.4	PASS
Low	N	100	3ppa Fluoro	125	243.0	4.7	4.2	36.6	PASS
Normal	N		7.5ppa Fluoro	125	242.0	8.4	7.5	65.4	PASS
High	Y		7.5ppa Fluoro	125	243.0	16.7	14.8	130.1	PASS
Low	N	120	3ppa Fluoro	125	244.0	7.4	4.0	34.8	PASS
Normal	N		7.5ppa Fluoro	125	243.0	14.0	7.5	66.0	PASS
High	Y		7.5ppa Fluoro	125	243.0	27.5	14.8	129.6	PASS



Maximum Output – Recorded Images

- Currently no limit!
- 30 cm from receptor
- We check min SID
- Many DSA programs have HIGH frame rates and should be checked
- Can be as high 1-2 Gy/min with Low frame rates
- Use caution when testing these modes as tube loading HU will increase rapidly

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Programming and setup of fluoroscope

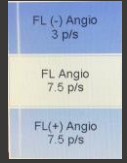
- Post installation personnel are VERY helpful and knowledgeable about their system.
- "Turnover team", Applications members and Field Service Engineers time on site is concentrated during installation and may overlap – presenting opportunities to assist in programming the system for use
- For identification purposes- naming conventions for programs should easily identify a Program with the Procedure intended to be performed, actual procedure may veer from Procedure started
- Typically, at least one good set of "Adult Programs" for use on Fluoro.
- A common procedure code or Lexicon may also aid in comparison of procedures across fluoroscopes.

Programming and setup of lab

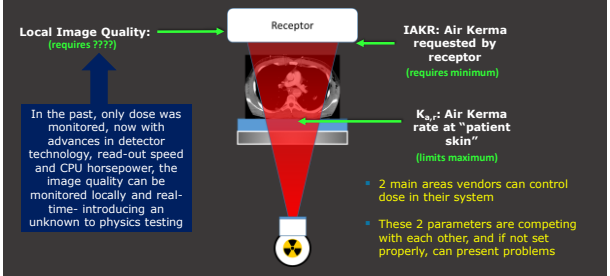
- Reference Point Dose from 2 Fluoro Rooms, Left not properly setup, Right with very descriptive Programs making it easy to identify trends or outliers.

Programming and setup Fluoroscopy Programs

- Many systems can use a set of Fluoro programs for Multiple procedures
- This allows for both fine tuning per separate procedure you set up, and the ability to use a common well tuned set of Fluoro programs across some or all procedures on the unit
- **Do not use the same Fluoro programs for Adult and Peds!**
- Many systems also have the ability for multiple levels of Fluoro, allowing a Low, Medium and High settings for those situations that provide opportunities for lower dose, or those situations that require more image quality or increased temporal fidelity



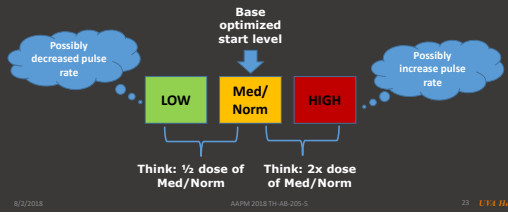
Programming and setup Fluoroscopy Programs



- 2 main areas vendors can control dose in their system
- These 2 parameters are competing with each other, and if not set properly, can present problems

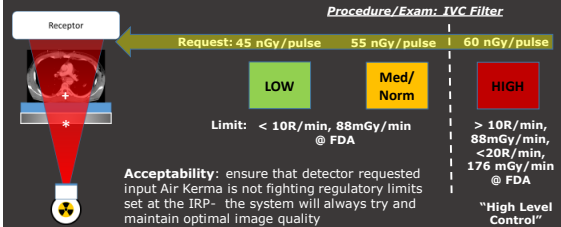
Programming and setup Fluoroscopy Programs

- Vendors have many methods for programming dose- check manuals or confer with FSE
- One approach is to setup the 3 levels of Fluoro with different dose levels AND possibly different pulse rates



Programming and setup Fluoroscopy Programs

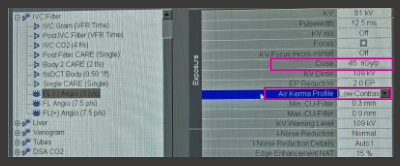
- Example programming: Interventional Radiography fluoroscope



Acceptability: ensure that detector requested input Air Kerma is not fighting regulatory limits set at the IRP- the system will always try and maintain optimal image quality

Programming and setup Fluoroscopy Programs

- Siemens Fluoro program settings for the LOW Fluoro setting
- Area in pink shows IAKR requested dose, and Low Contrast "profile" for RPAK location



Programming System Dose Alert Threshold Values

- Some fluoroscopes provide an option to pre-program a "soft stop" when pre-determined thresholds are exceeded to **Alert** fluoroscopist of increasing dose, and the possibility of a SRDL or Substantial Radiation Dose Level.
- NCRP 168 has valuable information on this
- Avoid alert fatigue

Table 4.7 Suggested values for 1st and subsequent notifications and the SRDL

Dose Metric	First Notification	Subsequent Notifications	SRDL
$D_{skin,max}$	2 Gy	0.5 Gy	3 Gy
$K_{a,r}$	3 Gy	1 Gy	5 Gy
P_{KA}	300 Gy cm	100 Gy cm	500 Gy cm
Fluoro Time	30 min	15 min	60 min

Radiation Dose Management for Fluoroscopically Guided Interventional Procedures, NCRP Report 168

Notification values currently set in IR Rooms at UVA:

1st Alert 4 Gy
2nd Alert 8 Gy
3rd Alert 14 Gy

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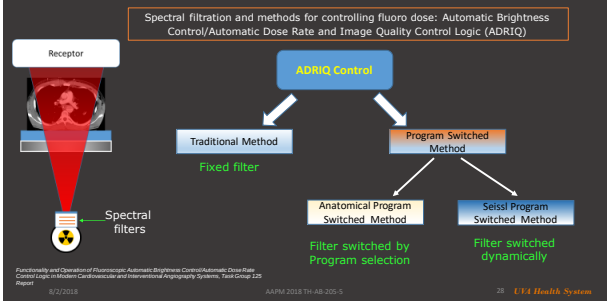
The work of Task Group 125

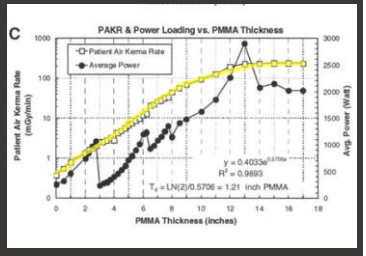


Functionality and Operation of Fluoroscopic Automatic Brightness Control/Automatic Dose Rate Control Logic in Modern Cardiovascular and Interventional Angiography Systems, Task Group 125 Report

Basic Fluoro Curves

Basic fluoro curves
- Low Dose
- Normal "anti Iso-watt"
- High Contrast

- Knowing how the curves are setup to perform may aid in adjustment later.
- These curves are only examples- there are variants
- TG-125 report shows how to measure and collect parameters from fluoroscopes to determine how the unit will operate clinically



Functionality and Operation of Fluoroscopic Automatic Brightness Control/Automatic Dose Rate Control Logic in Modern Cardiovascular and Interventional Angiography Systems, Task Group 125 Report

Patient Exposure measurements: TG-125 Method

- Measure RPAK with slabs of PMMA, with finer sampling of PMMA thickness near filter changes
- Collect pertinent parameters, mA, kVp, filter, ms… etc.
- Plot as needed – compare Levels of Fluoro to ensure they are doing what is intended
- Setup is reproducible – program settings likely aren't

- **Acceptance:** test all commonly used fluoro levels or programs with differing fluoro settings, this method is critical for units with dynamic filtration.

- **Acceptability:** Re-check multiples of PMMA, 6", 9", 12", some use 20cm, 30cm

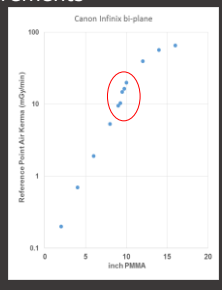
TG-125 measurements

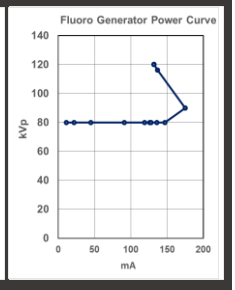
Dose curves from 2 Fluoroscopes used for different purposes, all 7.5 pps

Note similarities in curves.

Canon- Seissl method switched spectral filter

Philips –Program switched spectral filter

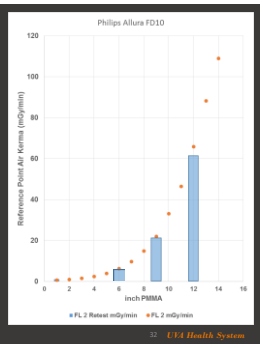




TG-125 measurements

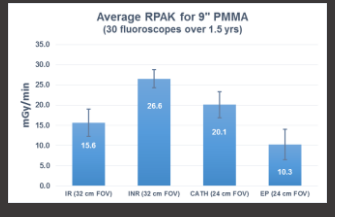
$K_{a,r}$ from system at acceptance vs. 1 year out

- **On Acceptance:** more detail or granularity can be tested-
- **Acceptability:** On annual retest of system, spot checking doses (blue bars) may be all that is necessary
- Differences shown from acceptance to retest are all <8%



Average Doses from Fluoroscopes per function

- Average values across 4 different fluoroscope types at UVA (representation from GE, Philips and Siemens units)
- Normal or "middle" Fluoro Level, 7.5 pps
- Detail work in the head likely driver for higher INR or Interventional Neuro dose rate
- Electrophysiology (EP) likely lower due to supplemental image guidance, and lengthy cases (dose rate is set lower)



Updates needed to TG-125 fluoro "curve" testing methodology

- Is the best document we have describing how these complex systems work, and how to test at least the fluoroscopy portion of the systems
- However, systems are getting more sophisticated, and image quality for given tasks is being monitored and changed locally within the image
- Adjustments are being made to images real-time, based on regional image metrics
- Therefore new testing methodologies must be examined to determine how the system operates at a basic level
- **TG-272 is tasked with shedding light on this issue**

Dose is not always the entire story

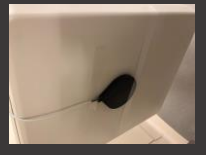
- Table at right shows system parameters from previous dose curves
- Note set IAKR values
- Fluoro program Norm to Low is roughly ½ $K_{a,r}$
- However, from Norm to High is delivering 3x the Air Kerma rate at the IRP

Parameter	Fluoro Low	Fluoro Norm	Fluoro High
pulse rate	7.5	7.5	15
kVp	78.4	68.4	68.4
Cu Filter (mm)	0.9	0.3	0.3
mA	98	98	112
$K_{a,r}$ (mGy/min)	**7.95**	**18.67**	**60.2**
Set IAKR (nGy/pulse)	29	36	55
Measured SNR (fluoro)	**51.5**	**56.8**	**53**

SNR tells an additional and different story- for a significant increase in Air Kerma, if we examine the Signal to Noise ratio from the corresponding Fluoro images- this program **may not** deliver the intended image quality increase desired

Measurement of Input Rate to Detector

- Input Air Kerma Rate to the Detector (IAKR)
- Formerly, possibly still "II Input dose"
- Service level measurement/calibration
- Not a good predictor of patient dose
- Currently no U.S. Regulation on receptor input exposure
- In the past – optical system could fail, and was used to control Fluoro and Recorded doses- those devices are now the exception
- To verify settings- IAKR must be measured as specified by vendor/manual



MITA White Paper out on this subject- stay tuned.

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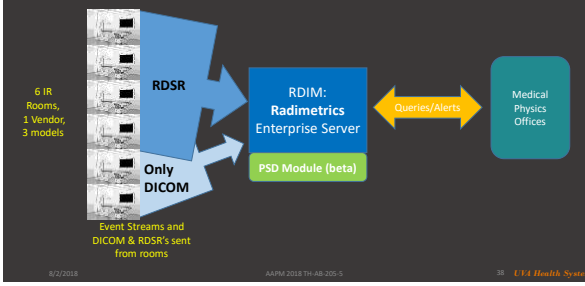
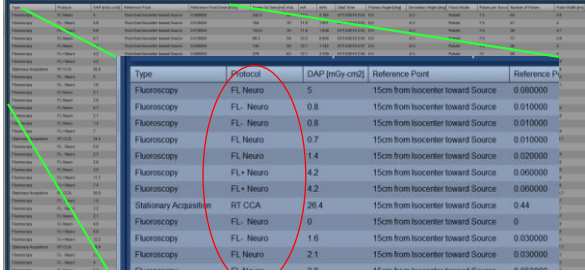
Tracking Interventional Doses at UVA: IR Structure/Layout



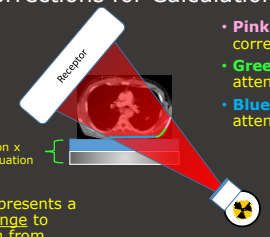
What do you need to track Interventional Doses?

Radiation Dose Structured Report or RDSR



Type	Protocol	DAP [mGy-cm2]	Reference Point	Reference Pt
Fluoroscopy	FL Neuro	5	15cm from Isocenter toward Source	0.080000
Fluoroscopy	FL- Neuro	0.8	15cm from Isocenter toward Source	0.010000
Fluoroscopy	FL- Neuro	0.8	15cm from Isocenter toward Source	0.010000
Fluoroscopy	FL Neuro	0.7	15cm from Isocenter toward Source	0.010000
Fluoroscopy	FL Neuro	1.4	15cm from Isocenter toward Source	0.020000
Fluoroscopy	FL+ Neuro	4.2	15cm from Isocenter toward Source	0.060000
Fluoroscopy	FL+ Neuro	4.2	15cm from Isocenter toward Source	0.060000
Stationary Acquisition	RT CCA	26.4	15cm from Isocenter toward Source	0.44
Fluoroscopy	FL- Neuro	0	15cm from Isocenter toward Source	0
Fluoroscopy	FL- Neuro	1.6	15cm from Isocenter toward Source	0.030000
Fluoroscopy	FL Neuro	2.1	15cm from Isocenter toward Source	0.030000

Necessary Corrections for Calculations



- **Pink** area no attenuation correction
- **Green** area Pad attenuation only
- **Blue** area Table and Pad attenuation

- This orientation presents a significant challenge to correct the beam from partial blockage of the Table and the Pad

Also consider, where is the patient on the table?

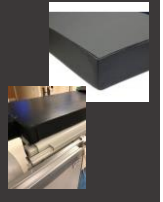
Geometrical Parameter Testing

- Computation of the Physical Geometry of the Fluoroscope with respect to the digital information coming from the system is critical to using the data within a RDIM

Example of determining of "lateral" table offset in the "Z" direction- difference between center of image and Z-axis or *Lateral* travel reported in the RDSR

Table Transmission Factor Determination

- Table and Pad collectively attenuate a significant amount of radiation while in the PA geometry
- Most vendors have 1 or 2 "tables" and once the properties are known – data can be recycled
- Tested typically under Service Mode or XR-27
- kVp and filter manually set
- Fixed detector – scatter free, with/without table and PAD in primary beam.
- Perform for range of useable kVp's/filters

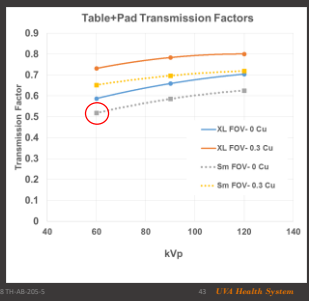


- **Accept** … or a range of clinical …
- **Accept** … and filter combina…

Warning: On General Fluoro rooms, where KW is lower than seen in IR/Cath units, a thick table pad can significantly drive up the ADRIQ

Table Transmission Factor Determination

- At low kVp and without Cu filter, this machine has significant attenuation of the beam, only **52%** is transmitted at 60kVp



Estimating Peak Skin Dose with data from RDIM

- Accurate calculation of Peak Skin Dose is not possible without corrections
- Beware of "Patient centric" vs. "Operator centric" coordinates in geometry

- Many if not ALL of the corrections can be obtained during **Acceptance**

DAP Meter correction ✓ → Geometric Corrections ✓ → Table/Pad Attenuation (or not) ✓ → Back Scatter (use tables ref. below) → f-factor

Jones et al. Journal of Applied clinical Medical Physics, Vol. 12, no. 4, Fall 2011

TG-246: Task Group on Patient Dose from Diagnostic Radiation

Charge

To summarize the current state of the art and outline a roadmap for standardized estimation of organ doses from medical imaging. Experts would be recruited from the appropriate subcommittees, including but not limited to, Informatics, CT, RFSC, and Mammography, with work between the subgroups being coordinated by the task group co-chairs. The roadmap would include information about how radiation was applied, the location of the patient with respect to the source of radiation, and the patient model and methods used to estimate organ doses. Standard reporting methods, quantities, and units will also be recommended.

Unit No. 21 - Fluoro

Task Group Report is being revised…stay tuned.

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Quality Control to ensure Acceptability

- A rigorous QC program serves to verify room readiness for lengthy, expensive and intricate procedures
- Often, units used for FGI's only have a yearly evaluation by physicist
- New Interventional equipment is often very complex, and can "phone home" to alert the vendor of issues, however….. is the system ready for a patient?

Snapshot of UVA IR QC program

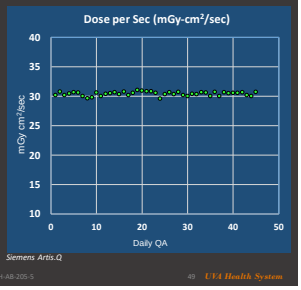
- Patient equivalent phantom evaluated every morning prior to patients
- Images of phantom preprocessed, results recorded into QC-Track*
- Currently evaluating **SNR**, kVp, mA
- See ePoster: "*#41137 -Use of signal to noise ratio for daily quality control of fluoroscopes used for interventional radiology procedures*" (this meeting)

With so much focus on Artificial Intelligence (AI) in Diagnostic Imaging, could QA also use AI for predictive analytics – possibly to predict when fluoroscopes or their components will go down??

* Atirix Medical Systems, Minneapolis, MN

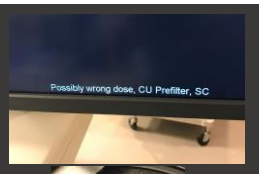
QC Case #1

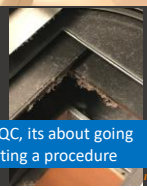
- KAP rate from Daily QC using patient equivalent phantom
- Rate is consistent over 2 months
- Changes in or failure of this value could indicate system output changes, KAP chamber changes, or both.



QC Case #2

- Indicator being displayed in an Interventional Suite
- Users "unaware" there is issue
- Astute QC tech should catch
- Issue- Copper filter "stuck" due to debris, lack of lubricant
- Errors such as this affect patient dose, system will operate in a compromised state





Sometimes its not about simply doing the QC, its about going through the motions OF QC BEFORE starting a procedure

Conclusions:

- There are a multitude of dose related tests that must be performed during Acceptance.
- Fluoroscopes used for FGI's are quite complex, and to understand how they work, additional testing may be needed beyond regulatory requirements.
- Advances in ADRIQ or dose rate controls on new systems may require image analysis in addition to checking doses to fully understand how the system is working.
- Recent software packages, or RDIM's provide tools for the physicist to remotely monitor doses and settings during clinical use.
- Geometry and or corrections to arrive at accurate a PSD may be required to supplement commercially available RDIM's.
- Acceptance testing may provide an opportunity to begin/continue a QC program. QC not only provides opportunities to spot check the health of the fluoroscope, but may assist in determining stability of dose delivered and to assess if the system is ready for complex procedures for the day.

THANK YOU!