

## INTRODUCTION

- The Joint Commission (TJC) instituted new provisions for providing fluoroscopy services in 2018 – *Standard PC.02.01.01*
- TJC recommends that facilities identify radiation exposure and skin dose threshold levels for patients of all sizes.
- Any examination that exceed these thresholds should trigger further review and if required, patient evaluation to assess adverse radiation effects.
- Radiation exposure thresholds can be established based on metrics such as reference-air kerma, cumulative-air kerma, kerma-area product or fluoroscopy time.
- However, for pediatric patients, establishing the thresholds are complicated due to large variation in patient size and correlation of dose to patient size.

## AIM

To provide empirical tools to set pediatric fluoroscopy quality assurance (QA) dose alert levels for any institution using data from a large pediatric hospital for general fluoroscopy, mobile-C-arms, interventional radiology (IR), and cath lab examinations by:

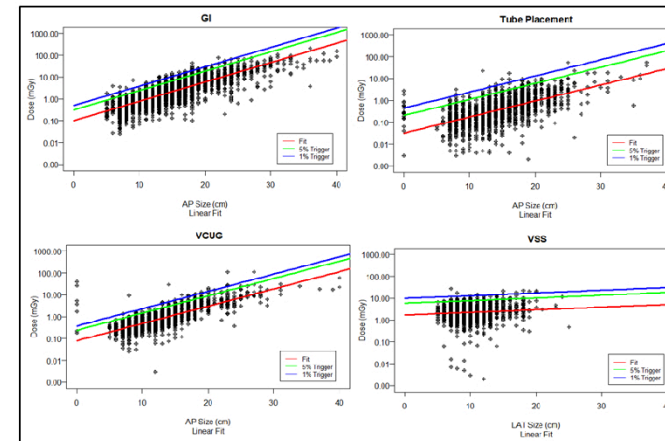
- Grouping examinations in each type of fluoroscopy room by their complexity and corresponding anatomy through expert consultation.
- Providing simple equations to establish trigger levels for each group of exams that are applicable to any institution after scaling by the institution's mean dose levels.

## RESULTS

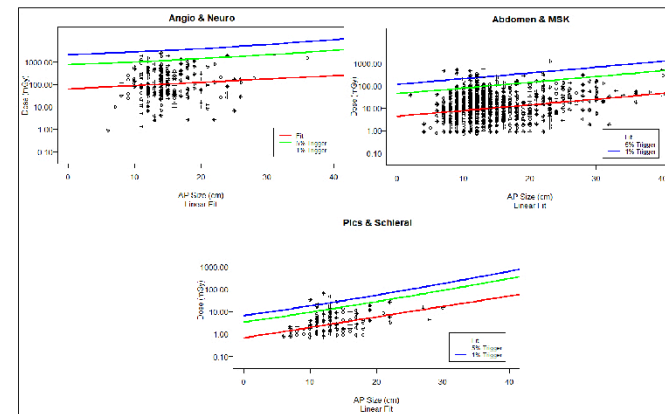
**Table 2:** Coefficients for calculating the dose alert levels for each procedure group in the 4 different modalities

General Fluoroscopy $K_{a,i}$ (mGy)						
Group	Slope (m)	$s_{\alpha}$ (Scaler 5%)	$s_{\alpha}$ (Scaler 1%)	Intercept (z)	Average Air Kerma (mGy)	Average thickness (cm)
GI	0.204	0.506	0.301	-2.294	1.758	14.032
TP	0.171	0.468	0.248	-3.451	0.369	14.470
VCUG	0.183	0.575	0.398	-2.537	0.833	12.926
VSS	0.030	3.190	4.098	0.542	2.253	9.793
Interventional Radiology $K_{a,i}$ (mGy)						
Group	Slope (m)	$s_{\alpha}$ (Scaler 5%)	$s_{\alpha}$ (Scaler 1%)	Intercept (z)	Average Air Kerma (mGy)	Average thickness (cm)
Angio + Neuro	0.048	1.505	1.716	4.156	106.118	15.030
Abdomen + MSK	0.061	2.528	3.163	1.482	10.084	14.160
Pics + Schleral	0.122	-2.228	-3.586	-0.386	2.666	12.712
CATH lab Frontal Plane $K_{a,i}$ (mGy)						
Group	Slope (m)	$s_{\alpha}$ (Scaler 5%)	$s_{\alpha}$ (Scaler 1%)	Intercept (z)	Average Air Kerma (mGy)	Average thickness (cm)
Diagnostic	0.084	7.649	10.414	0.268	4.684	15.714
Low	0.102	4.122	5.432	0.458	4.711	12.257
Medium	0.165	3.372	4.361	0.730	21.168	14.481
High	0.152	2.648	3.334	1.139	30.330	15.256
CATH lab Lateral Plane $K_{a,i}$ (mGy)						
Group	Slope (m)	$s_{\alpha}$ (Scaler 5%)	$s_{\alpha}$ (Scaler 1%)	Intercept (z)	Average Air Kerma (mGy)	Average thickness (cm)
Diagnostic	0.070	27.007	37.829	0.094	5.099	22.448
Low	0.074	3.346	4.331	0.693	6.706	17.597
Medium	0.120	4.973	6.630	0.447	19.611	21.293
High	0.141	18.083	25.199	0.117	24.220	21.935
Mobile C-arms $K_{a,i}$ (mGy)						
Group	Slope (m)	$s_{\alpha}$ (Scaler 5%)	$s_{\alpha}$ (Scaler 1%)	Intercept (z)	Average Air Kerma (mGy)	Average age (years)
Low	0.049	-3.814	-5.810	-0.537	0.994	10.845
Medium	0.055	6.697	9.059	0.414	2.642	10.206
High	0.092	3.802	4.970	1.010	6.868	9.990

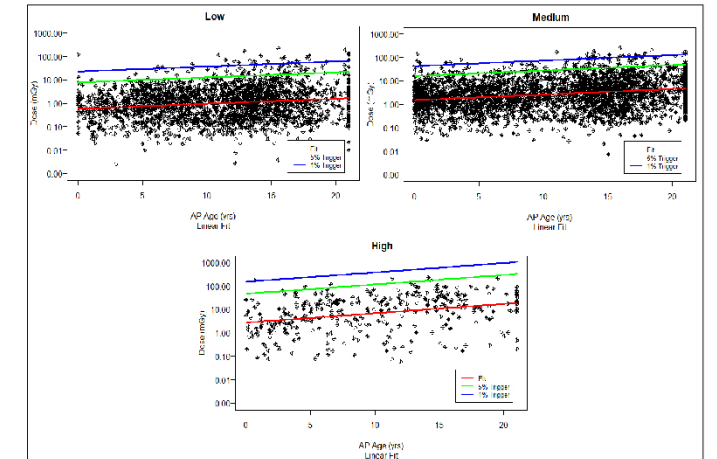
**Figure 1:** Plots for general fluoroscopy (GF) groups with the dose fit and the upper prediction interval boundaries for 5% and 1% levels.



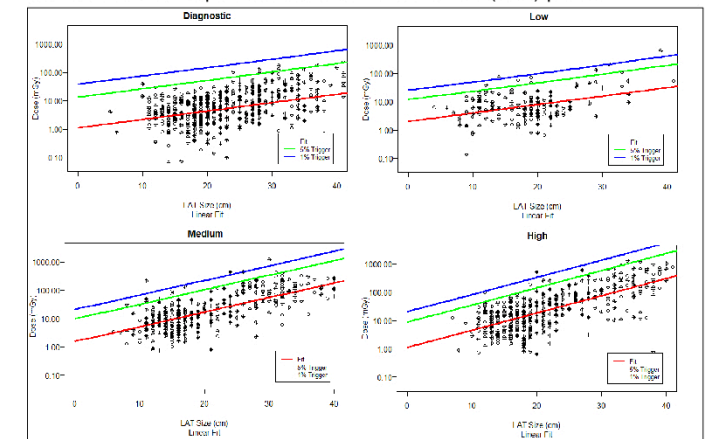
**Figure 2:** Plots for interventional radiology (IR) groups with the dose fit and the upper prediction interval boundaries for 5% and 1% levels.



**Figure 3:** Plots for mobile c arms (MC) dose groups with the linear fit and the upper prediction interval boundaries for 5% and 1% levels.



**Figure 4:** Plots of the regression fit and the upper prediction boundaries for Cath lab procedures as a function of patient thickness in the lateral (LAT) plane.



**Table 1:** Procedure groupings for the 4 fluoroscopy rooms along with the descriptions of exams in each group

Room	Groups
General Fluoro (GF)	Gastro Intestinal (GI)
	Voiding Cystourethrogram (VCUG)
	Video Swallow Study (VSS)
	Tube Placement (TP)
Mobile C arms (MC)	Low dose
	Medium dose
	High dose
Interventional Radiology (IR)	Abdomen & Mucoskeletal (ABM)
	Angio & Neuro (AN)
	Pic lines & Schleral (PS)
Cath lab (Cath)	Diagnostic studies
	Interventional low
	Interventional medium
	Interventional high

- The dose alert levels can be estimated for each room and dose group using the equation:

$$\hat{D}_{\alpha}(x_{pat}) = EXP(m x_{pat} + s_{\alpha} z), \quad Eq. 1,$$

$\hat{D}_{\alpha}$  - Dose trigger in milligray for a given  $\alpha$  level (5% or 1%)

$x_{pat}$  - Patient thickness in centimeters

$m$  - Slope of the upper prediction boundary

$s_{\alpha}$  - Ratio of the intercepts of the dose fit to the upper prediction boundary

$z$  - Intercept value of the linear dose fit

- $z$  can be calculated for each institution based on the average dose ( $D_{avg}$ ) for their average sized patient ( $x_{avg}$ ) using:  

$$z = \ln(D_{avg}) - m * x_{avg}, \quad Eq. 2$$

- $m$  and  $s_{\alpha}$  are predetermined constants presented for each modality and dose group listed in Table 2.

## METHODS

- Air kerma data ( $K_{a,i}$ ) along with patient thickness (AP or LAT) were collected for fluoroscopic examinations: general fluoroscopy (11,132 exams), IR (1500 exams), and cath lab (1573 exams) from 10/2016 through 12/2019. For mobile-C-arms (6145 exams), patient age was used as a surrogate to patient thickness because patient thickness data was not available, .
- Based on the complexity of the procedure and the body anatomy that is imaged, all the common procedures with similar dose levels are combined into groups.
- The normality of the dose data for each procedure group was assessed visually using QQ (*quantile-quantile*) plots and logarithmic transformation was used to transform the data into a normal shape.
- The log-transformed dose data is fitted as a function of patient thickness measured in the AP or LAT dimension based on the procedure for all fixed modalities using a linear regression model.
- To set the dose alert levels, the upper limit of the prediction interval for the linear fit was calculated.
- For easy implementation, the prediction interval upper boundaries for two different  $\alpha$  values (for 5% and 1% levels) were plotted and linear regression fits of these plots were calculated. The coefficients of these linear fits provide a direct estimate of the dose alert levels.

## CONCLUSIONS

Grouping of fluoroscopy examinations based on complexity and the anatomy of interest for general fluoroscopy, IR, mobile-C-arms and cath lab for dose monitoring purposes has been devised.

An empirical equation to estimate fluoroscopy dose alert levels for pediatric patients based on patient size has been developed using dose and size data collected over a period of 3 years at a large academic pediatric institution.

**A method to adapt and scale any institution's patient data to create alert levels for that institution's pediatric examinations has been presented.**

## CONTACT INFORMATION

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