A Systematic Analysis of the Error Sources within the CyberKnife M6 Daily AQA Test

Kevin T. Jordan MS[1,2], Alan Mayville MS[1], Tewfik Bichay PhD[1]
Mercy Health Lacks Cancer Center, Dept. Rad. Oncology, Grand Rapids MI[1]
Wayne State University School of Medicine Dept. Rad. Oncology, Detroit MI[2]

Introduction

To determine and critically analyze the sources of error within the daily Automatic Quality Assurance (AQA) test used on the CyberKnife M6 system, noting that nominal accuracy is < 1 mm.

Figure 1. CyberKnife M6 Standard Room Setup

Methods

Figure 2. AQA Error Source Breakdown Chart

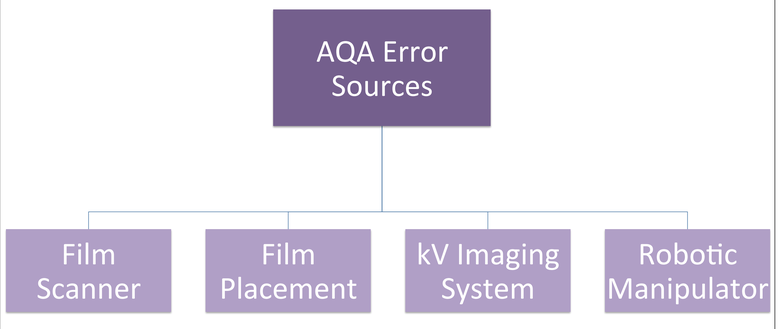
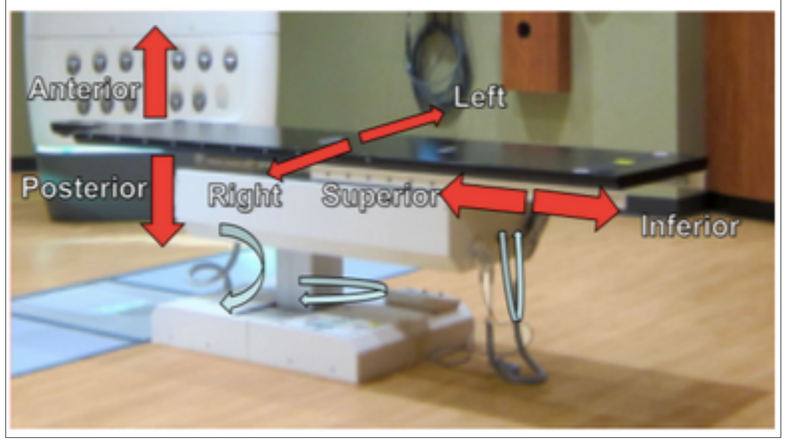


Figure 3. Translational & Rotational Couch Corrections



Results

Equation 1. Radial Error Calculation

$$Radial\ Error = \sqrt{Offset_{Inferior}^{Superior\ 2} + Offset_{Left}^{Right\ 2} + Offset_{Posterior}^{Anterior\ 2}}$$

Figure 4. IRIS – Film Scanner Repeatability (±1SD)

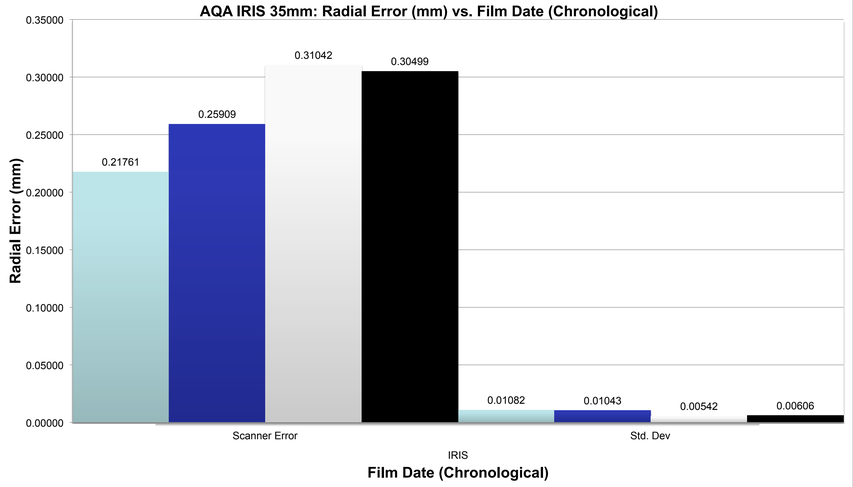


Figure 5. IRIS – Film Placement Repeatability (±1SD)

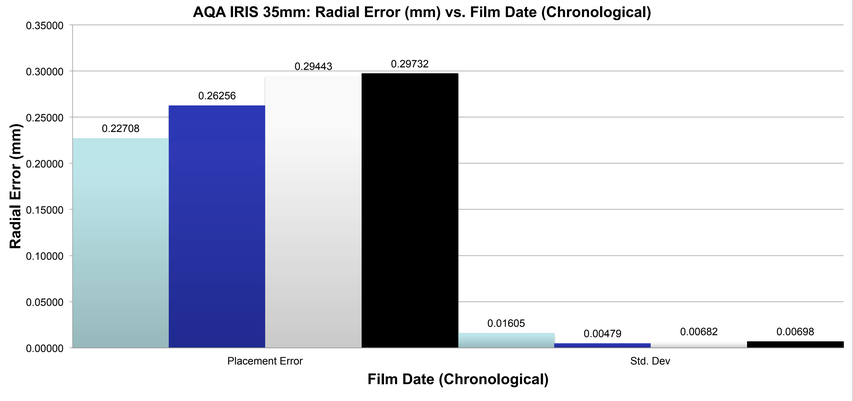
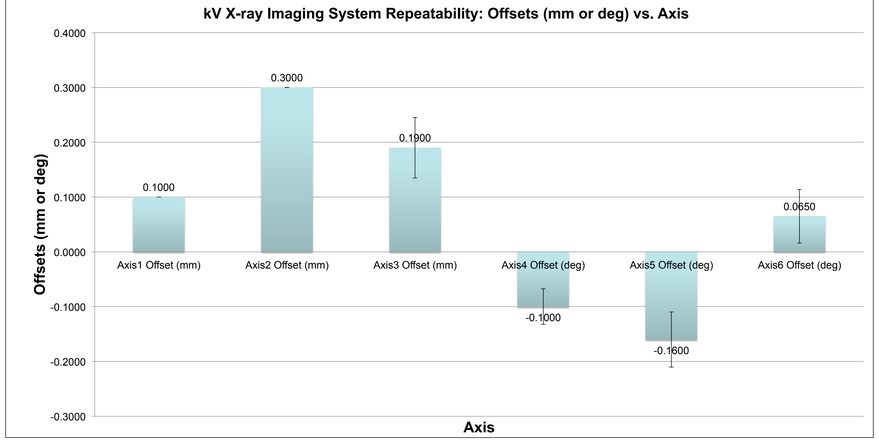


Figure 6. kV Imaging System Repeatability (±1SD)



Results continued

Table 1. Robot Repeatability Using SRS Profiler

CyberKnife M6 -- Robot Localization Repeatability				
No.	X (cm)	Y (cm)	Positive Diagonal (cm)	Negative Diagonal (cm)
1	-0.05	0.02	-0.03	-0.05
2	-0.05	0.02	-0.03	-0.05
3	-0.05	0.02	-0.03	-0.05
4	-0.05	0.02	-0.03	-0.05
5	-0.05	0.02	-0.03	-0.05
6	-0.05	0.02	-0.03	-0.05
7	-0.05	0.02	-0.03	-0.05
8	-0.05	0.02	-0.03	-0.05
9	-0.05	0.02	-0.03	-0.05
10	-0.05	0.02	-0.03	-0.05
Average (cm)	-0.05	0.02	-0.03	-0.05
Std. Dev (cm)	0.00	0.00	0.00	0.00
Std. error	0.00	0.00	0.00	0.00

Conclusions

The total AQA uncertainty appears to be largely due to the kV imaging system. These results suggest an uncertainty of less than 0.1 mm for the film, film scanner, and robot components of the AQA test. The kV imaging system uncertainty could reach 0.3 mm and is the main source of uncertainty. This information explains greatest weakness in daily CyberKnife QA and may be useful in establishing realistic expectations of daily AQA results.

Table 2. Itemized & Maximum Uncertainty – IRIS & FIXED

CyberKnife M6 Treatment Delivery Uncertainties - IRIS	
Uncertainty Source	***Uncertainty, mm, +/- 3SD***
Flat Bed Film Scanner	0.025
Film Placement	0.001
kV Imaging System Fiducial Tracking	0.150
Robot Mechanical*	0.173
Total Uncertainty, mm, +/-3SD	***0.349***
CyberKnife M6 Treatment Delivery Uncertainties - FIXED	
Uncertainty Source	***Uncertainty, mm, +/- 3SD***
Flat Bed Film Scanner	0.015
Film Placement	0.001
kV Imaging System Fiducial Tracking	0.150
Robot Mechanical*	0.173
Total Uncertainty, mm, +/-3SD	***0.339***

Figure 7. Tolerance Stackup on Daily AQA Films