Intelligent Noise Reduction: Seeing Through the Noise with Deep Learning Image Processing

Technical White Paper

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Introduction

Canon has developed a convolution neural network (CNN)-based image processing procedure for projection radiography to produce high quality images with reduced patient radiation dose. The product is called "Intelligent NR" by Canon, or Intelligent Noise Reduction (INR). INR can be used with CXDI detectors by activating varying levels of noise reductions ranging from being turned off completely up to its highest level of noise reduction (level 10) which results in no loss of fine detail. The CNN was trained to eliminate the noise by reproducing the frequency characteristic of noise at tens of millions of input patterns to consider the frequency characteristics of noise at any dose levels. This white paper will look at the challenges of conventional noise reduction, improvements with INR, and performance data of INR in phantom images.

Challenges of Conventional Noise Reduction Techniques

In general radiographic images, the noise is typically proportional to the square root of the signal. Conventional noise reduction by Canon has been done using a rule-based processing to manually separate the signal and the noise in the images based on the image characteristics of CXDI detectors. This has led to improvements in image noise and contrast-to-noise ratio. However, limits have been reached on the amount of noise that can be reduced using these methods, making further improvements difficult for low dose areas of images.

Development of Machine Learning Techniques for Noise Reduction

Machine learning has now been introduced to many imaging modalities. Canon has implemented machine learning for the characteristics of noise in DR images as the driving force behind their INR to discriminate much more complex characteristics than the manually created rules used in previous iterations of noise reduction. "This has allowed the separation of signal and noise to be done more accurately by reproducing the frequency characteristic of noise through tens of millions of input parameters. While conventional noise reduction was unable to consider the frequency characteristics of noise that change depending on the dose level, INR provides adequate noise reduction at any dose level for CXDI flat panel detectors" [1]

The processing of images using the original convolutional neural network optimized for the CXDI series of the detector allows for implementation of INR without changing the workflow significantly. The time for INR processing is kept to approximately two seconds while maintaining high performance. [1]

Performance of Intelligent Noise Reduction in Limiting Image Noise

Previous studies have shown that there is no loss of MTF after applying the highest setting of conventional or intelligent noise reduction when using the edge method and an RQA5 quality beam. While Conventional NR has demonstrated inclusion of some parts of the signal in the removed component, INR has been shown to reduce this issue (Figure 1). [1]

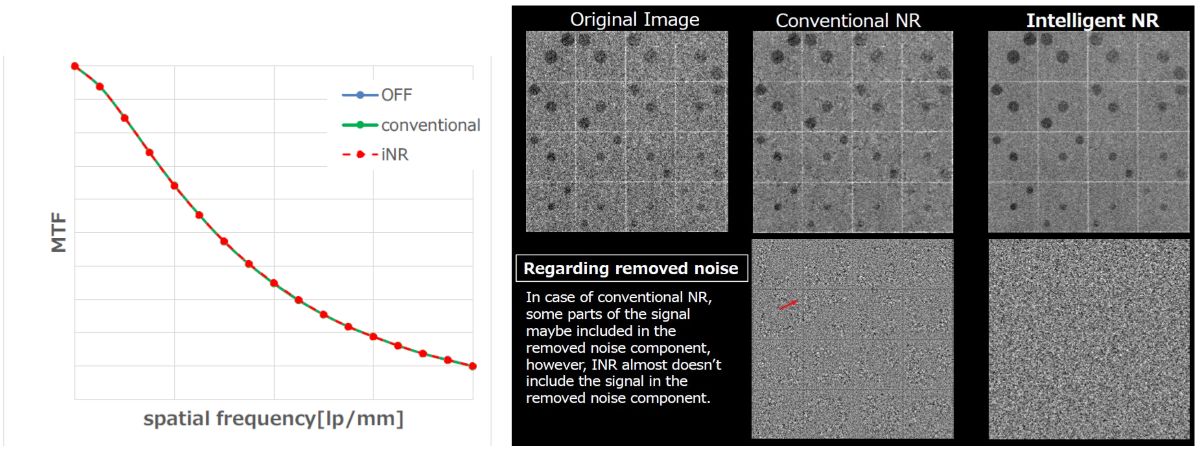

Figure 1 Noise Reduction MTF and Noise Removed Images

Table 1

kVp	mAs
50	2.5
60	5
70	8
80	10
90	12.5
100	14
110	18
120	20

In this study, phantom images of the "Duke" Digital Phantom 07-646 were used to quantify noise reduction in heart, lung, and diaphragm areas of a chest radiograph, shown in Figure 1, under different exposure settings shown in Table 1. These images were taken in the bucky with INR off, INR level 10, and INR level 3. The procedure was repeated on the tabletop for INR off and INR level 10. This gave 64 images and 192 data points for each case.

Figure 2 Duke Phantom Regions of Interest

Examples of identical exposures with INR and without INR are included in Figures 3 and 4.

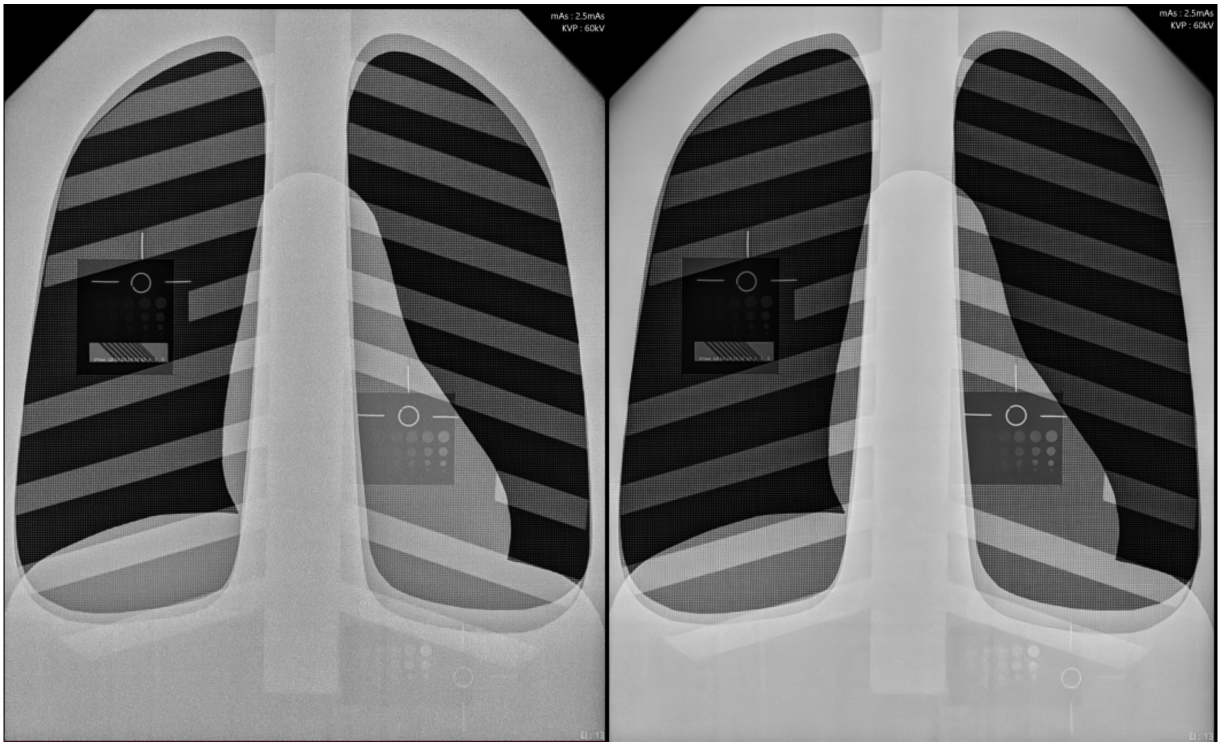

Figure 3 Conventional NR (Left) and INR (Right)

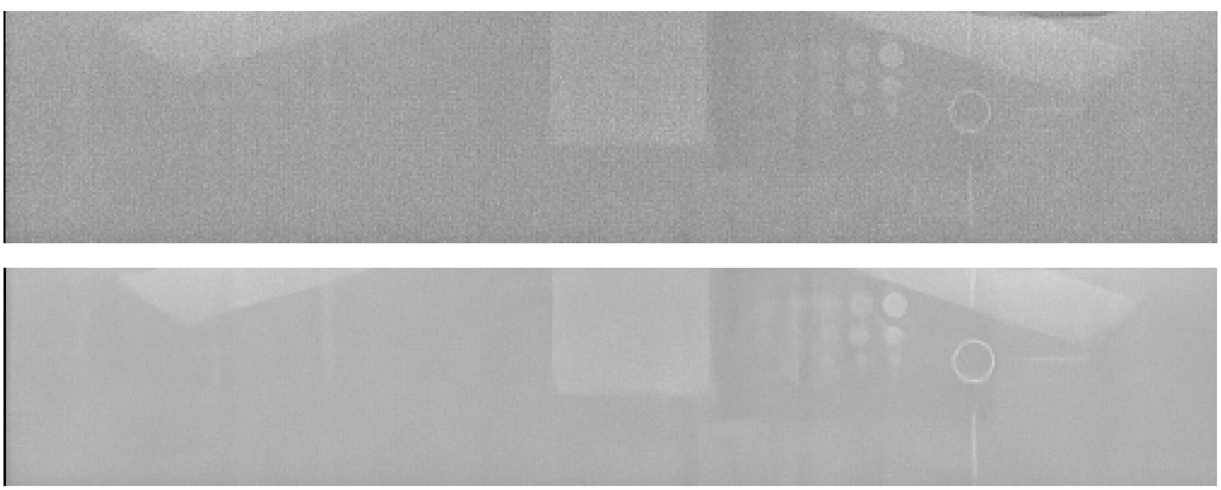

Figure 4 Diaphragm Section of Conventional NR (Above) and INR (Below)

The data was analyzed for trends in each combination of kVp, region of interest, and detector setup. All data is shown, but some cases were not in the diagnostic range of exposures because of insufficient radiation or detector saturation. Graphs of Noise vs. mAs are included in Appendix A and SNR vs. mAs in Appendix B. These graphs show significantly reduced noise for the images with proper exposure levels at the detector. The noise is decreased by a factor of two to three in most instances within the diagnostic range of doses.

Some examples of instances where the radiation levels were non-diagnostic are from the subsets of the diaphragm area of the table bucky images that utilized 50 kVp and 120 kVp. In the case of 50 kVp, the exposures lead to negligible amounts of radiation at the detector and left little to no differentiation with changing mAs. In the case of 120 kVp along with the higher mAs settings at 100 kVp and 110 kVp, the detector became saturated, and the data shows noise trends that are level instead of decreasing with increased dose. The INR appears to reach a point where the image noise reduction has been maximized. At this point, increasing the dose no longer has a significant impact on the noise. In normal diagnostic ranges, the dose reduction follows the expected curve of lowering the noise as the mAs increases. The SNR at the lower dose levels shows improvements in SNR similar to those seen in the ability to reduce noise. Once again, at higher dose levels, the improvements in SNR while using INR are not seen.

Conclusion

Intelligent Noise Reduction is effective at improving the quality of images by reducing the overall noise in the images. The primary goal of INR is to reduce the noise in images or areas of images with lower dose to the detector. Data from the phantom images clearly show the promise and ability of INR to reduce the noise in these lower dose ranges which should lead to improved diagnostic quality of images. This should also allow images to be acquired with lower doses and still maintain the image quality needed for diagnostic tasks.

Appendix A: Noise vs. mAs

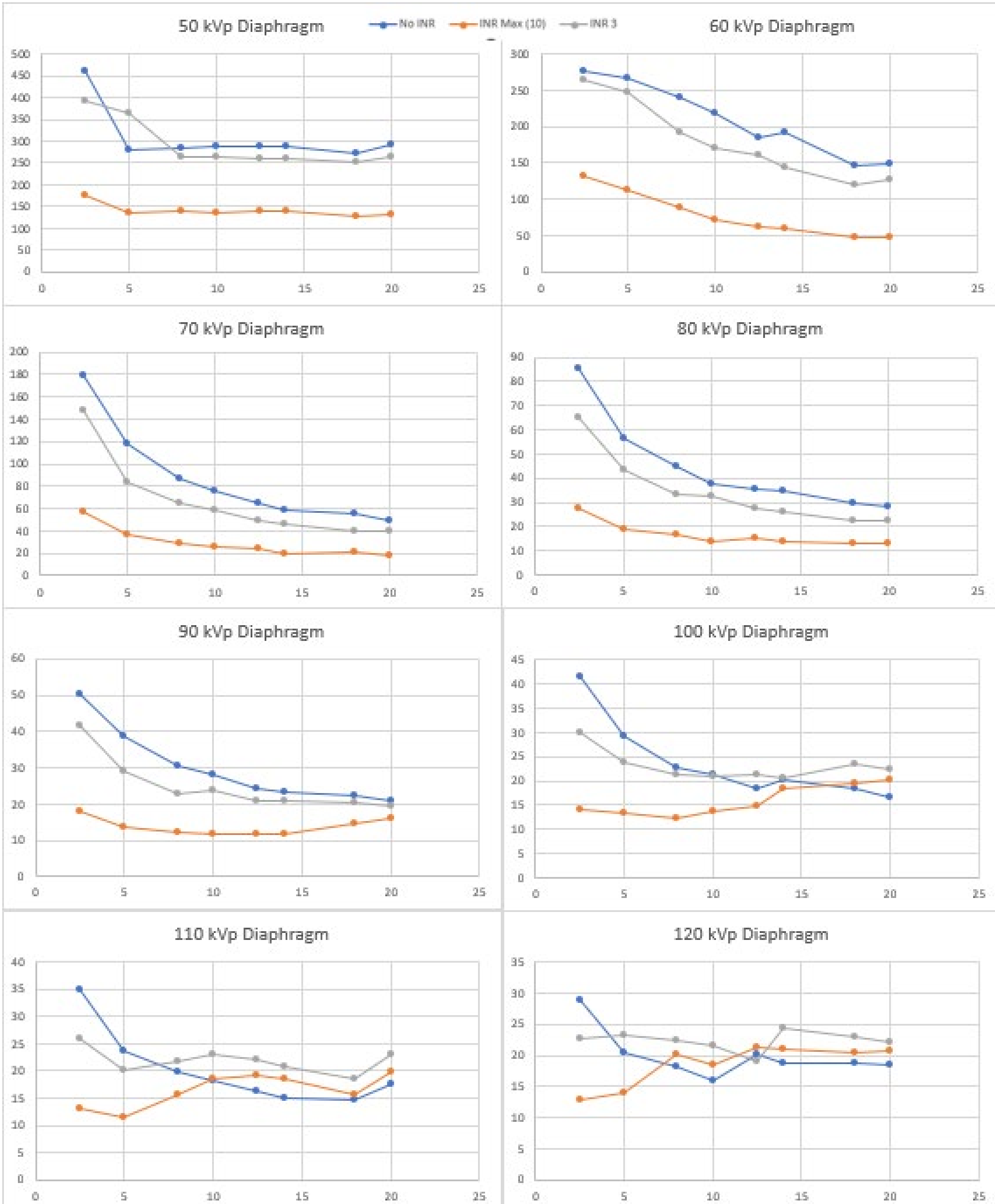

Figure 5 Table Bucky Diaphragm Noise vs. mAs

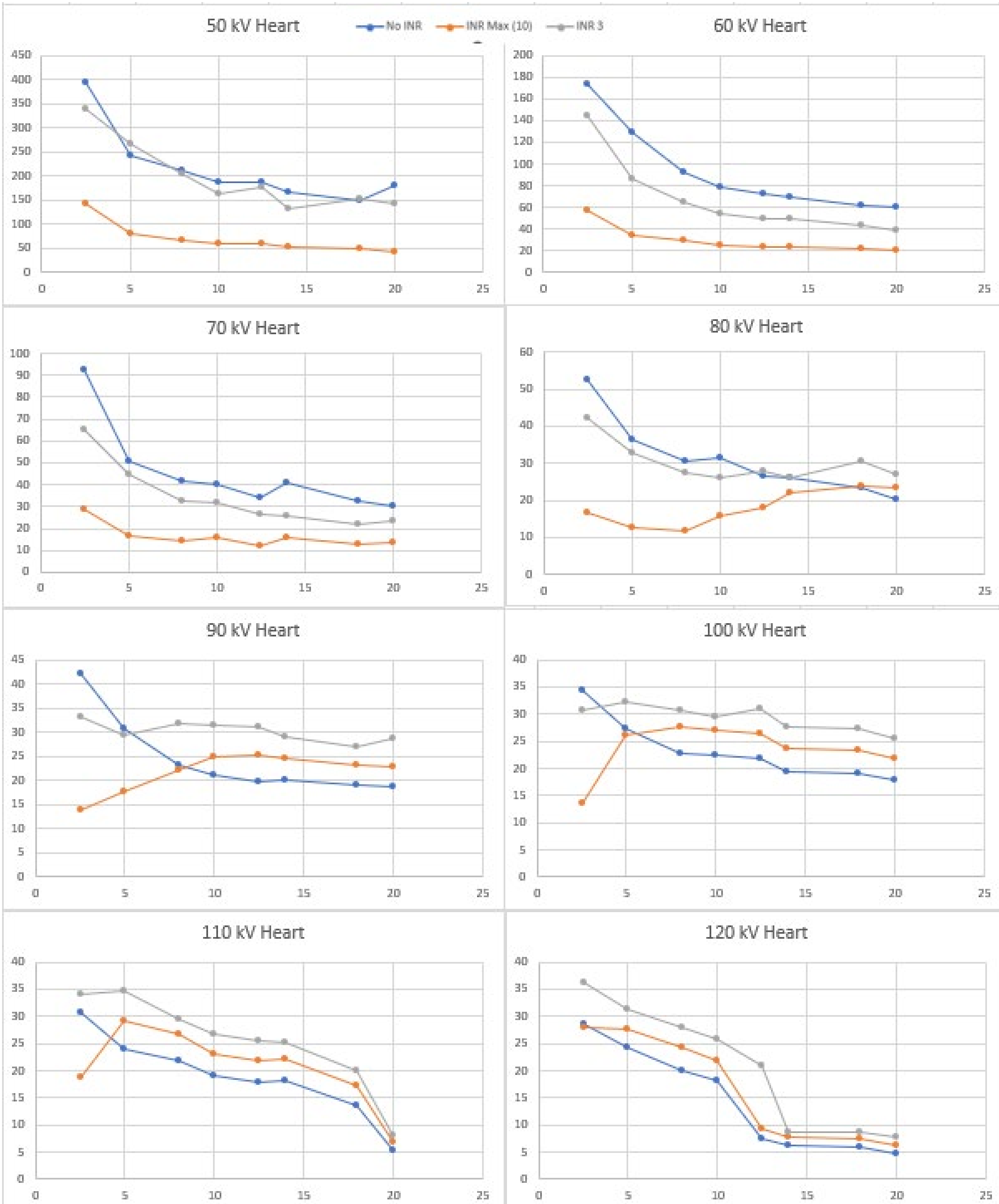

Figure 6 Table Bucky Heart Noise vs. mAs

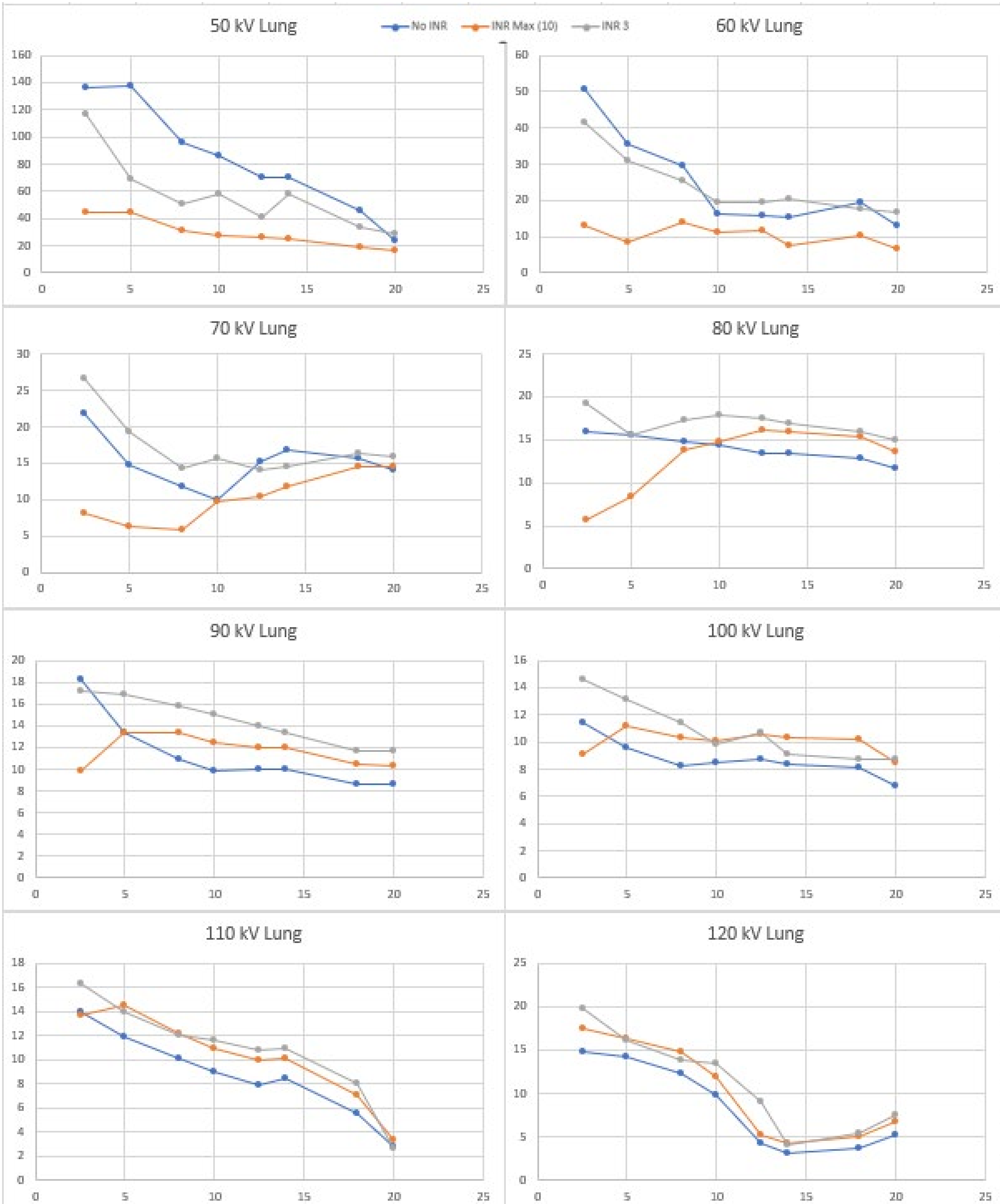

Figure 7 Table Bucky Lung Noise vs. mAs

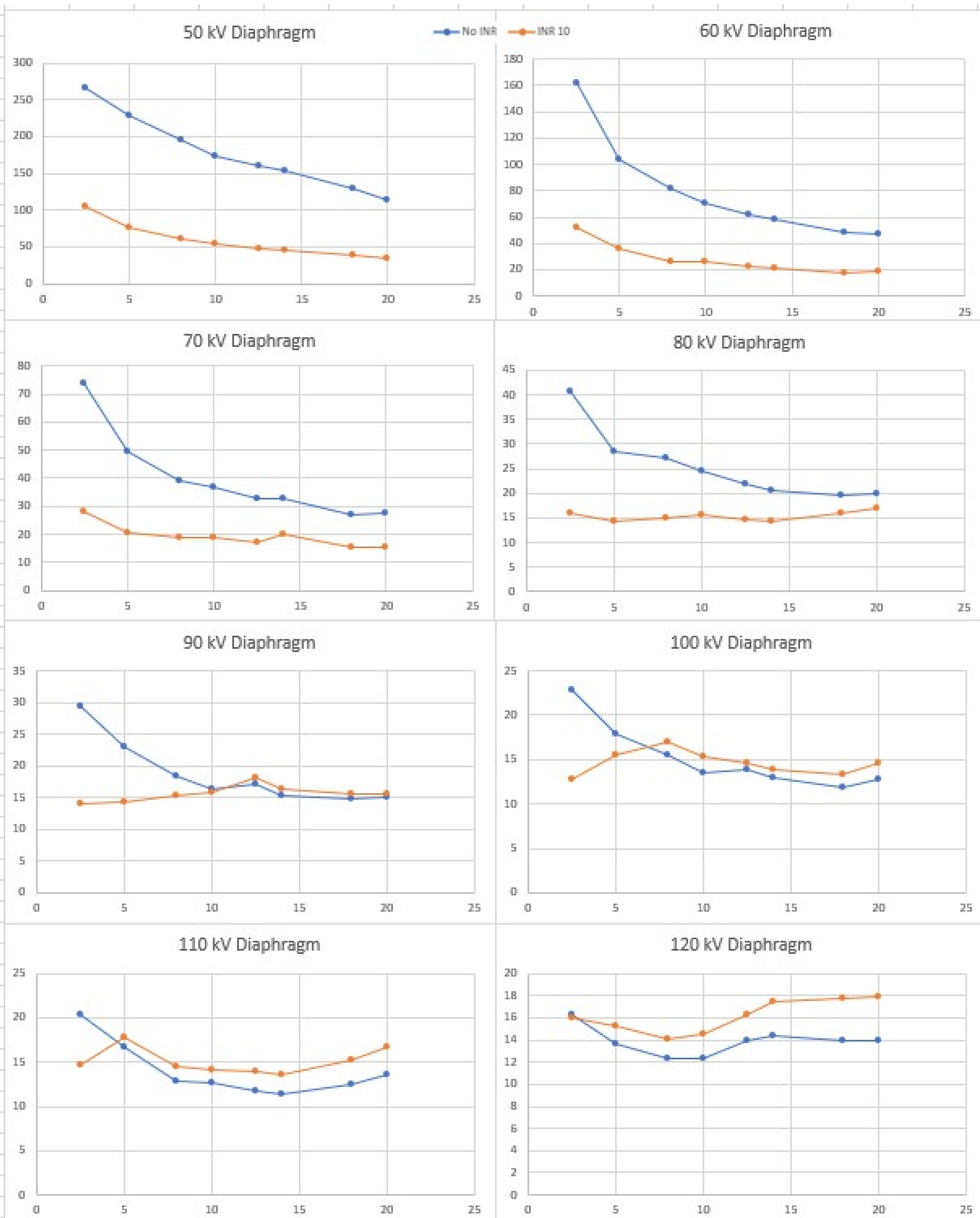

Figure 8 Tabletop Diaphragm Noise vs. mAs

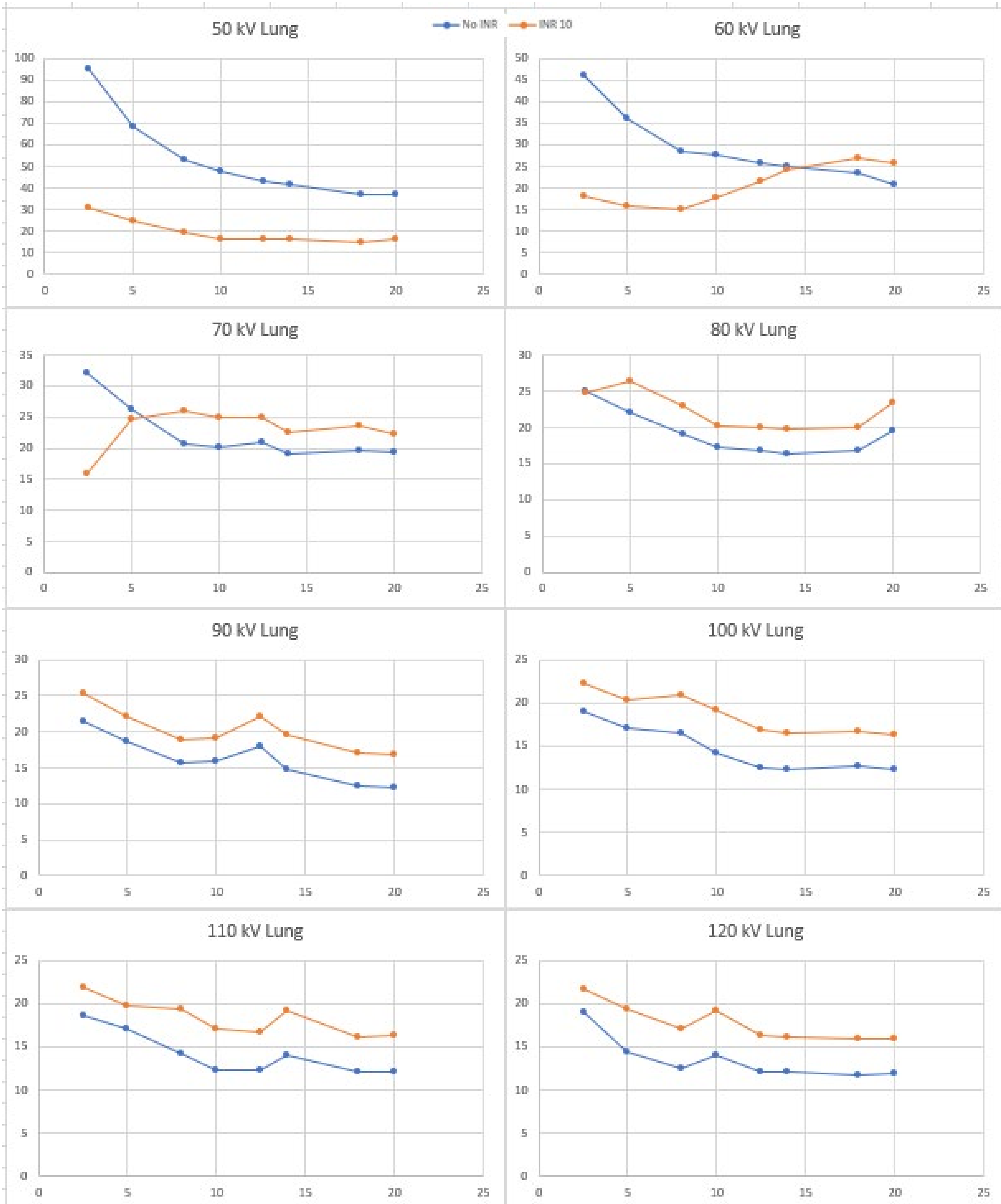

Figure 9 Tabletop Lung Noise vs. mAs

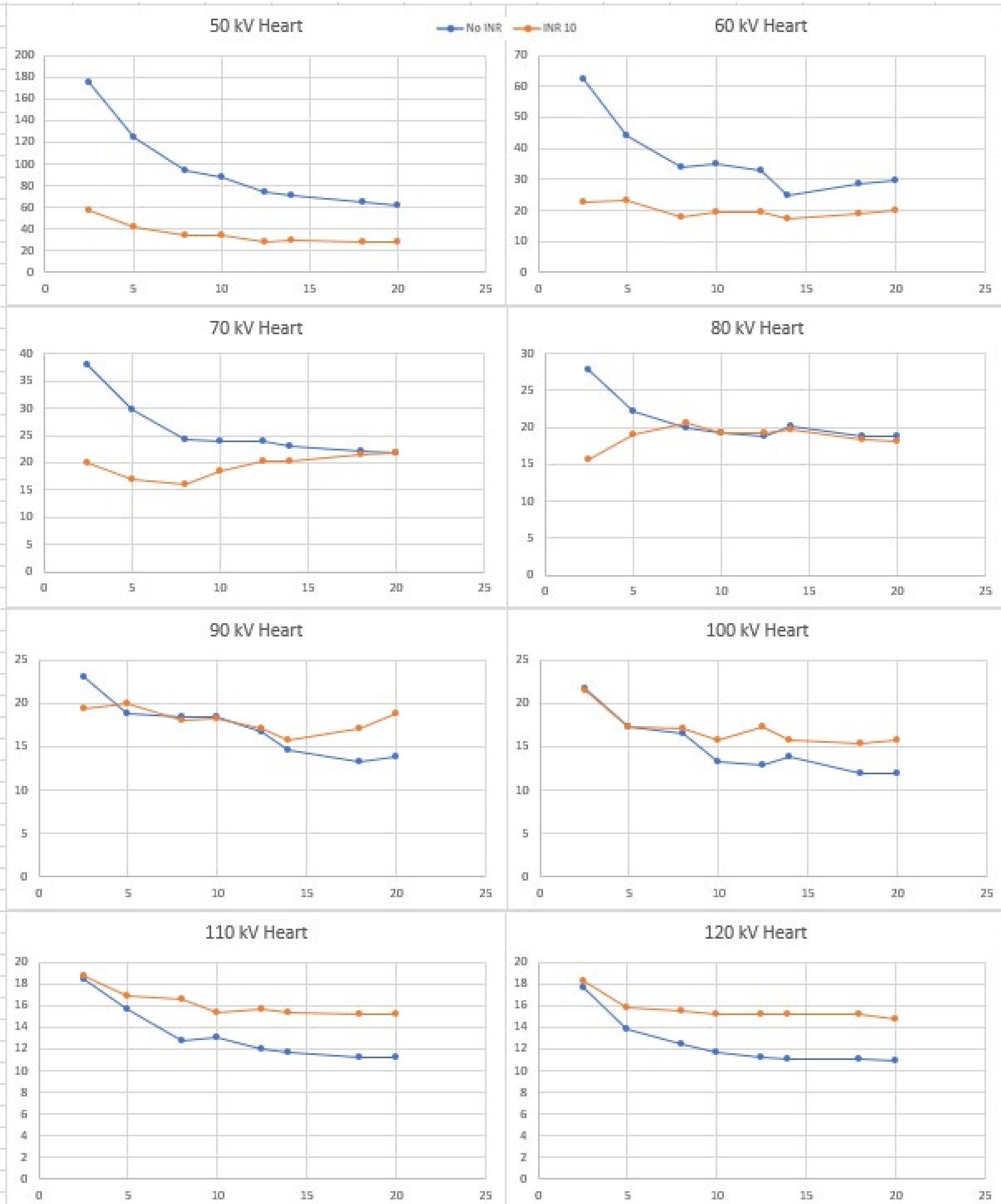

Figure 10 Tabletop Heart Noise vs. mAs

Appendix B: SNR vs. mAs

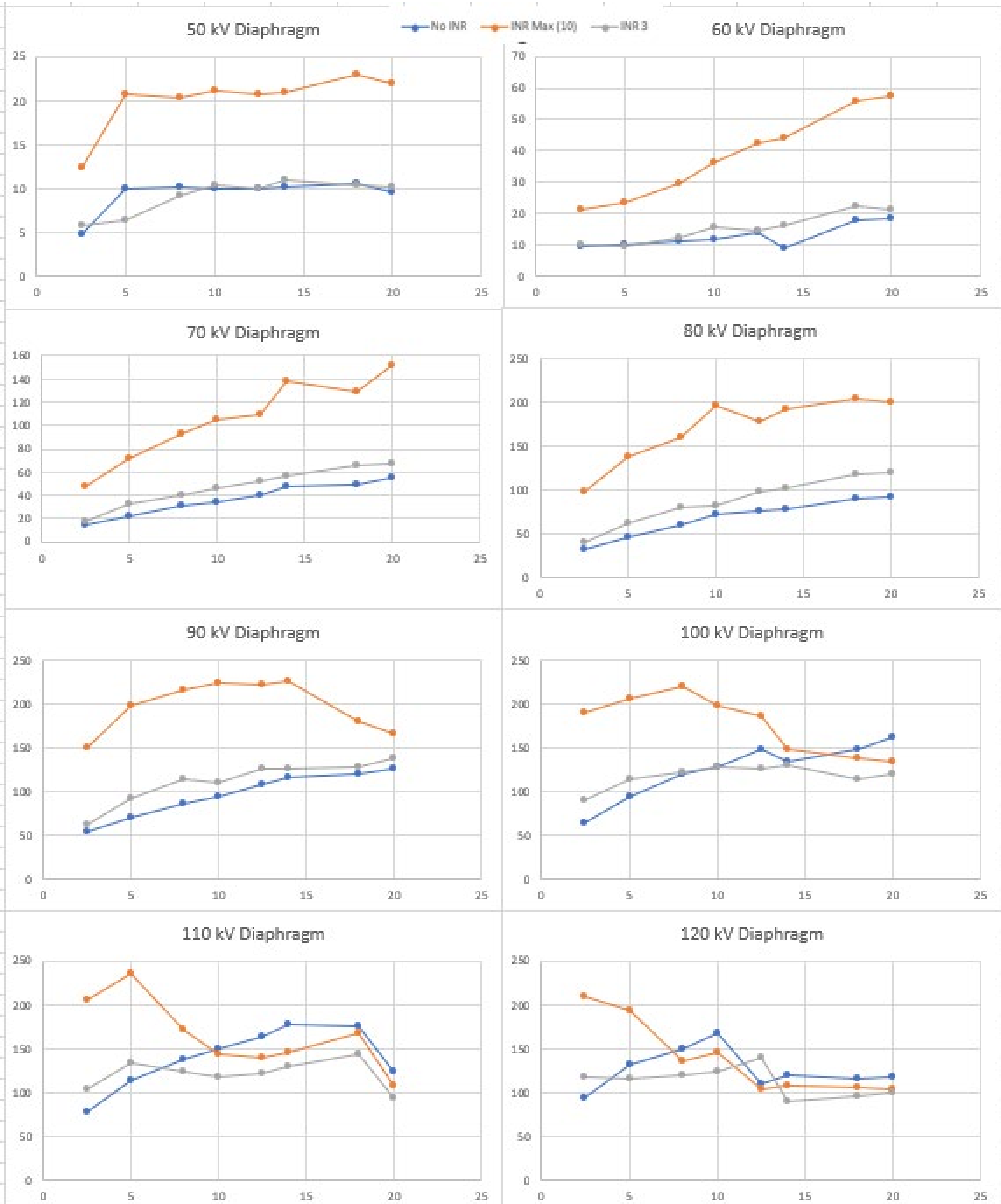

Figure 11 Table Bucky Diaphragm SNR vs. mAs

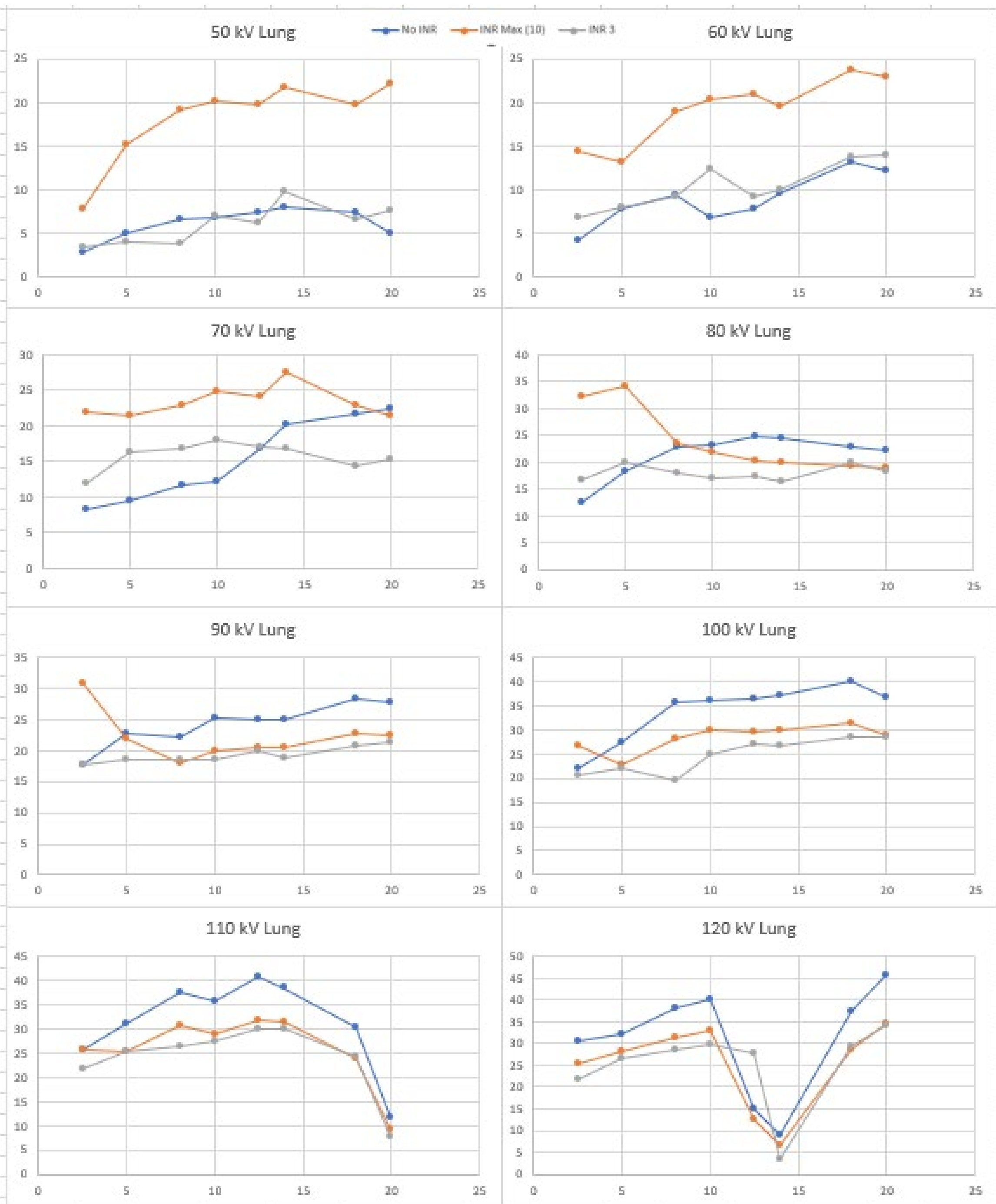

Figure 12 Table Bucky Lung SNR vs. mAs

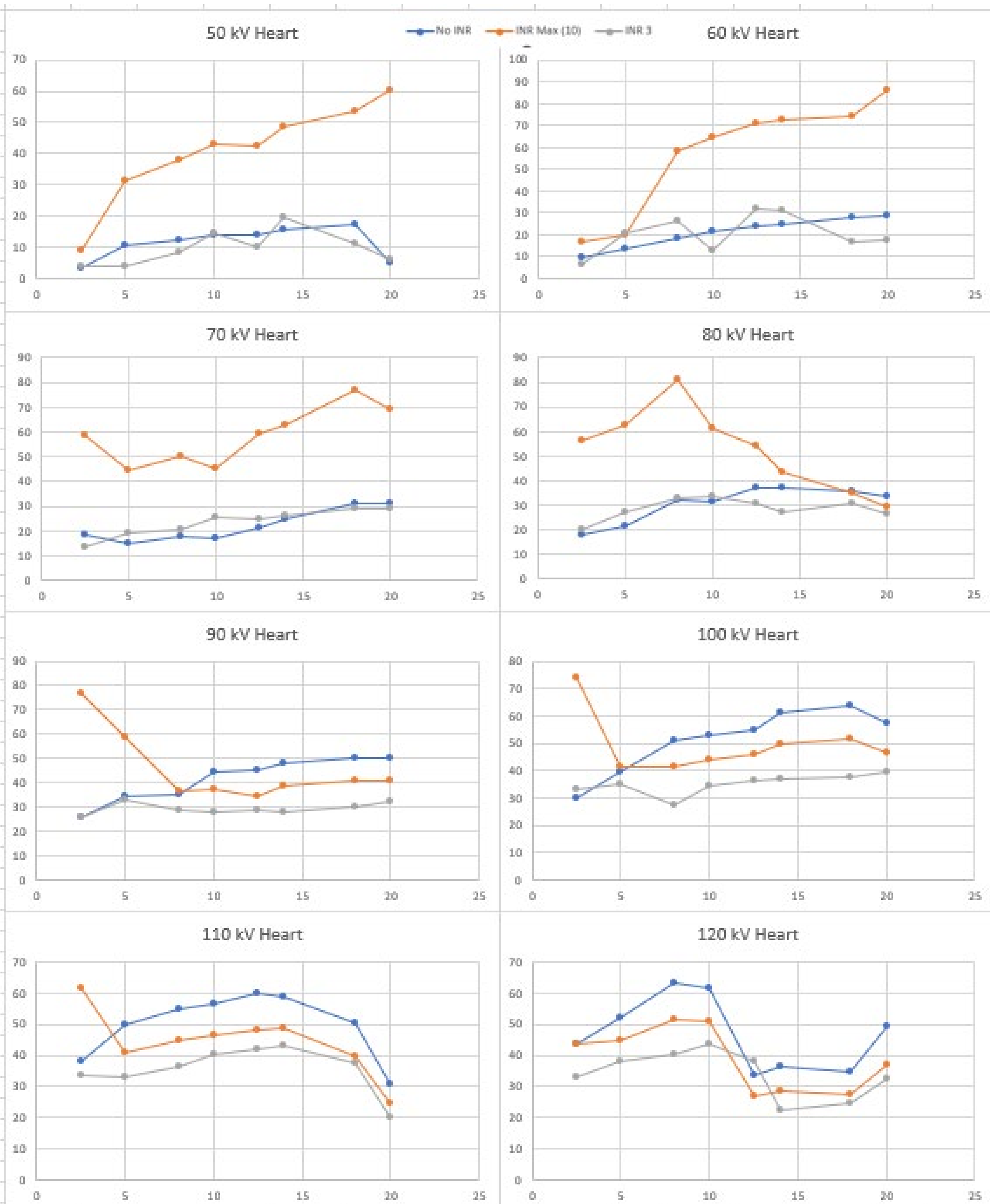

Figure 13 Table Bucky Heart SNR vs. mAs

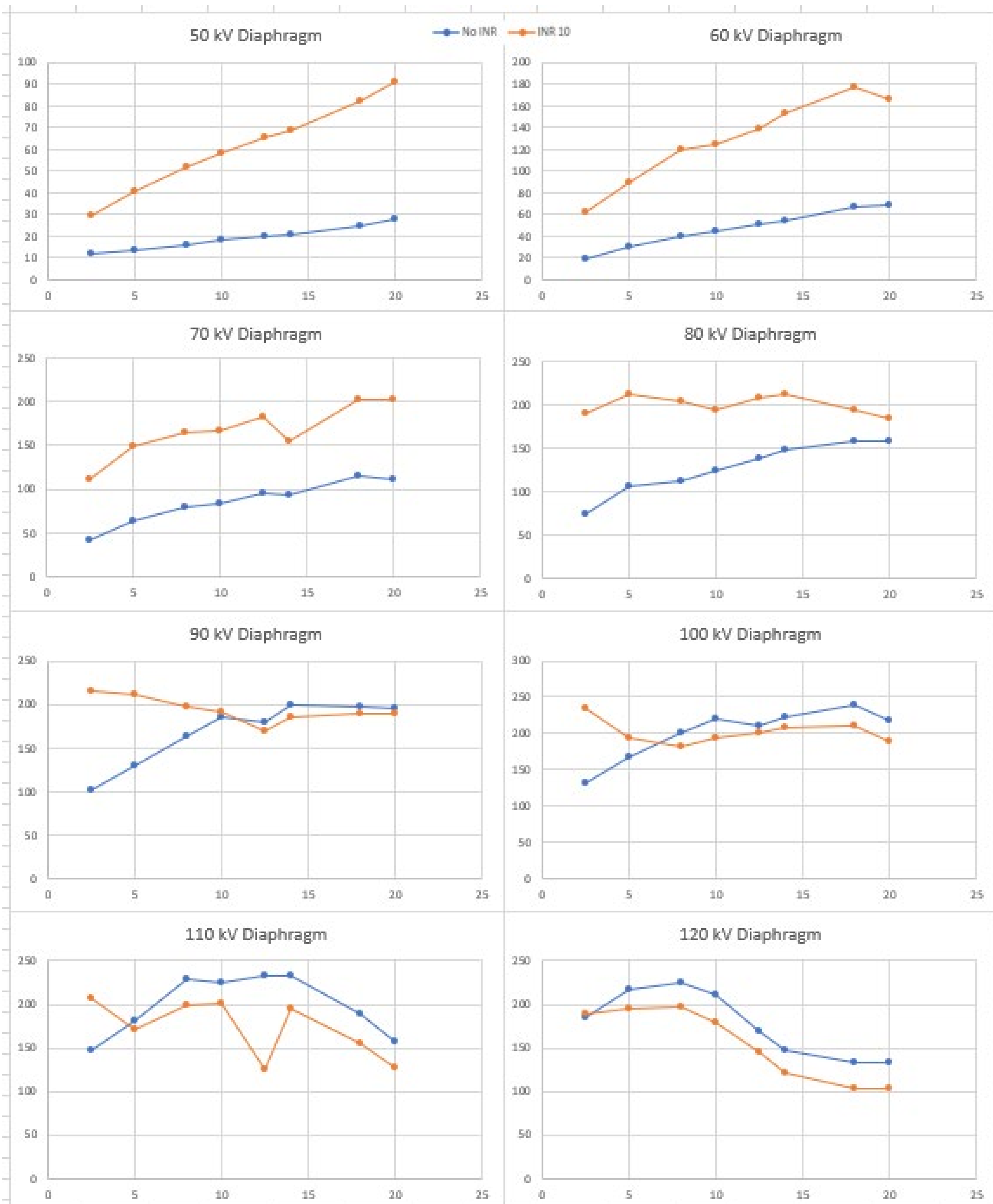

Figure 14 Tabletop Diaphragm SNR vs. mAs

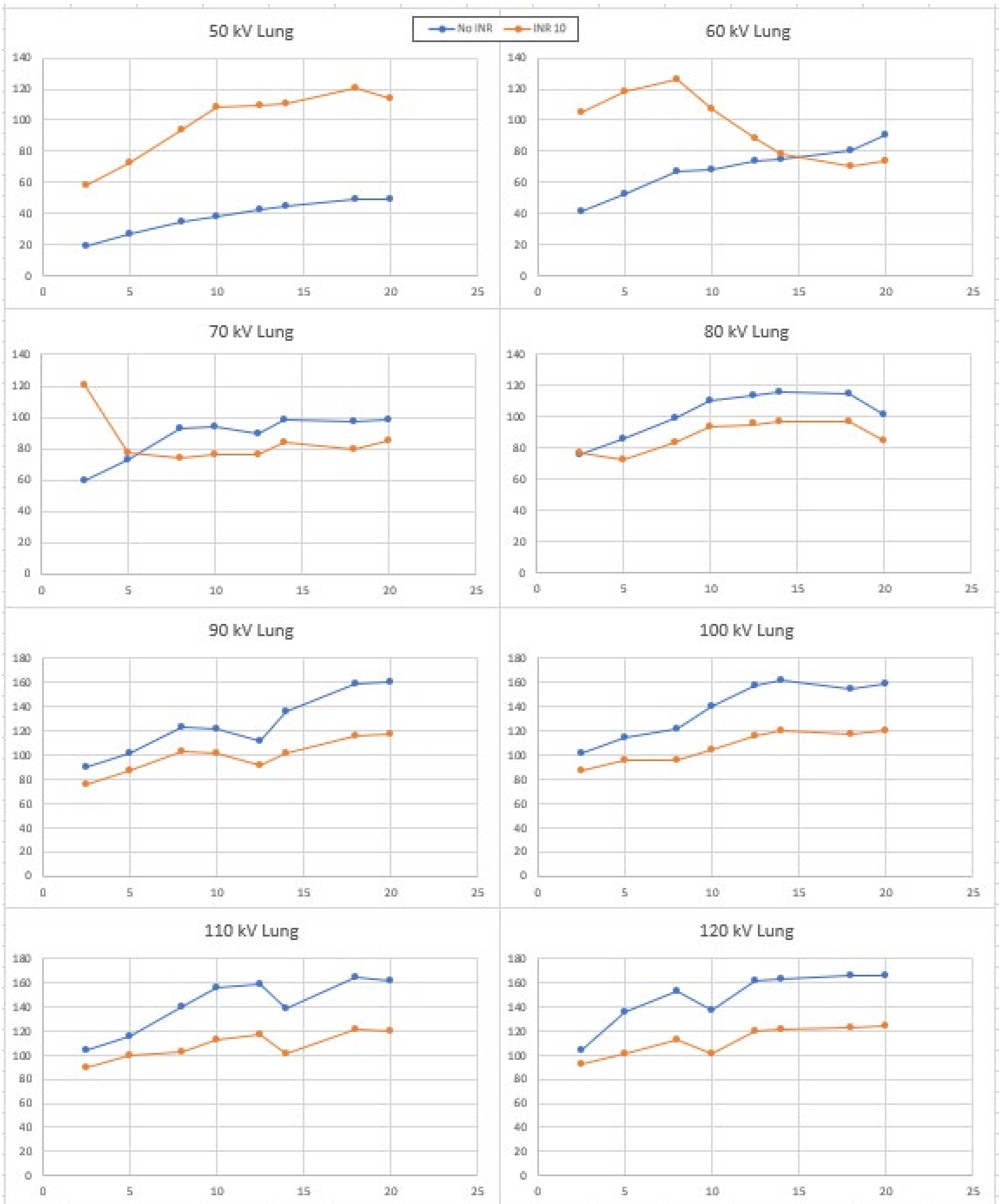

Figure 15 Tabletop Lung SNR vs. mAs

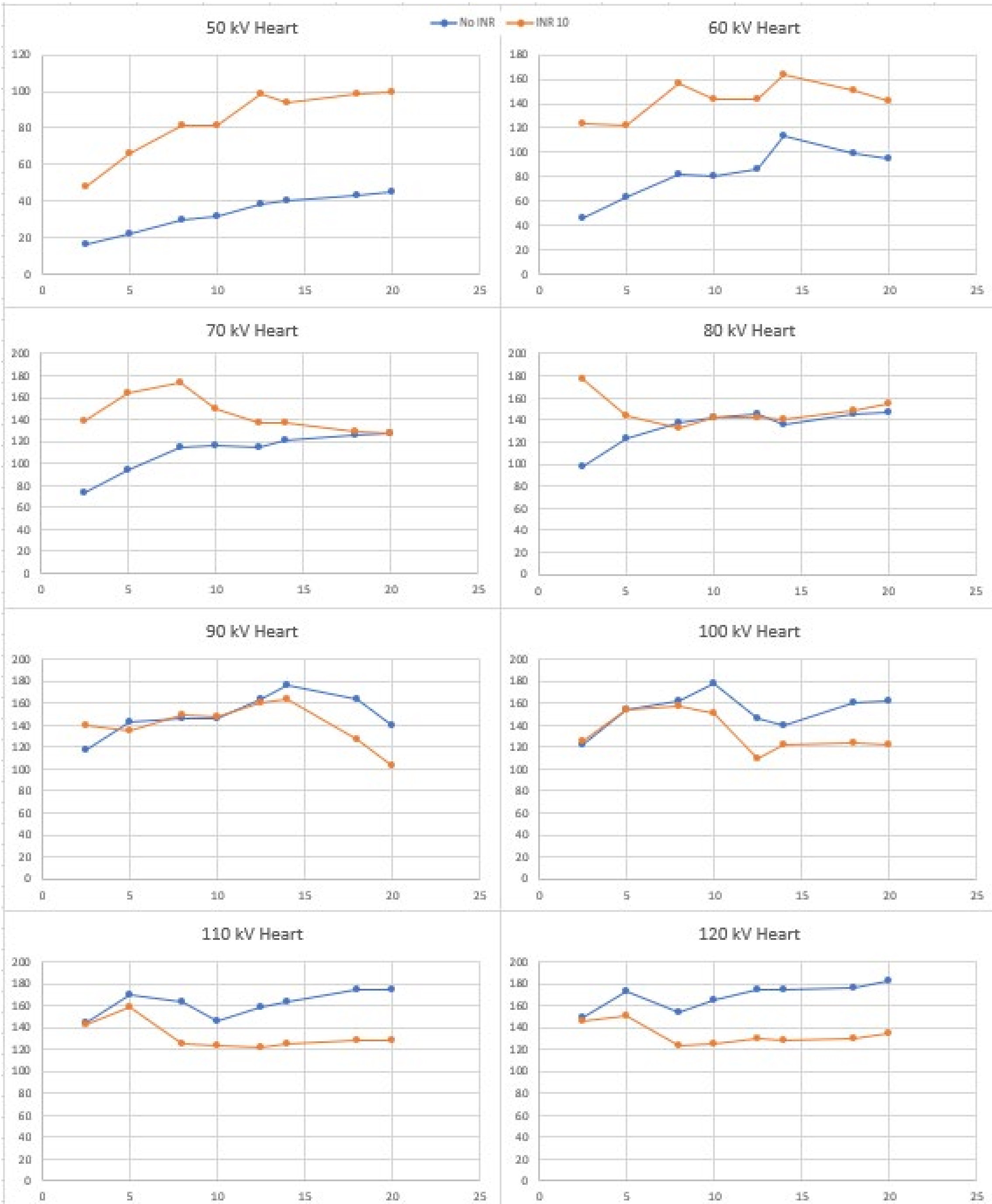

Figure 16 Tabletop Heart SNR vs. mAs

References

1 Canon Inc., Medical Component Business Unit, Medical Equipment Development Center, Medical Equipment Development Div 2. “Intelligent NR Technical Description”