White Paper

The Advantages of Hybrid Gamma PXL

CONTENTS

No.17-001 Revision A

November 2017

Product & Business Development Dept.

Product Technology section

1 Introduction

With advances in medical imaging technology over the years, hospitals are now handling a wider variety and larger volume of image data. As a result, it is increasingly common for medical facilities to use a variety of color and monochrome imaging modalities to interpret images. Advanced display technology such as high brightness, high contrast color LCD devices also accelerates this trend of reading various color and monochrome imaging modalities on one screen.

However, there is a fundamental technical challenge when it comes to displaying both monochrome and color images on one screen, while ensuring image display conditions to be appropriate for each modality. In other words, monochrome images must be displayed with standardized gamma characteristics, which are quite different from these of color images.

DICOM (Digital Imaging and Communications in Medicine) part 14 defines specific gamma characteristics for monochrome images called GSDF (Grayscale Standard Display Function). It is commonly used for Monitor QC assessment and judgment criteria, and is standardized by organizations worldwide such as AAPM, DIN, JIRA, and IEC.

On the other hand, gamma characteristics called Gamma 2.2, which are sRGB defined, are very commonly used for displaying color images across the medical imaging workflow from acquisition to viewing.* (Fig. 1)

Currently some medical grade monitor technologies are available to switch between DICOM Grayscale images and colored Gamma 2.2 values in order to display both monochrome and color images with accurate and appropriate gamma curve. (Fig.2) It normally requires manual operation and it is still not possible to display monochrome and color images at the same time on one screen.

The Hybrid Gamma PXL is designed to solve this problem. The Hybrid Gamma PXL enables the display of both monochrome and color images with appropriate gamma characteristics without any manual operation. The Hybrid Gamma PXL function automatically distinguishes between monochrome and color images pixel by pixel, creating a hybrid display where each pixel has optimum grayscale; giving it greater accuracy and reliability.

In this technical white paper, we outline this innovative technology, and discuss how this function fully complies with the DICOM part 14 standard while optimizing color medical images, by introducing a recent study conducted by Kumamoto Chuo Hospital in Japan.

* The American Association of Physicists in Medicine (AAPM) and International Color Consortium (ICC) is working to standardize criteria to display color medical images because there is not any criteria and standard for them.

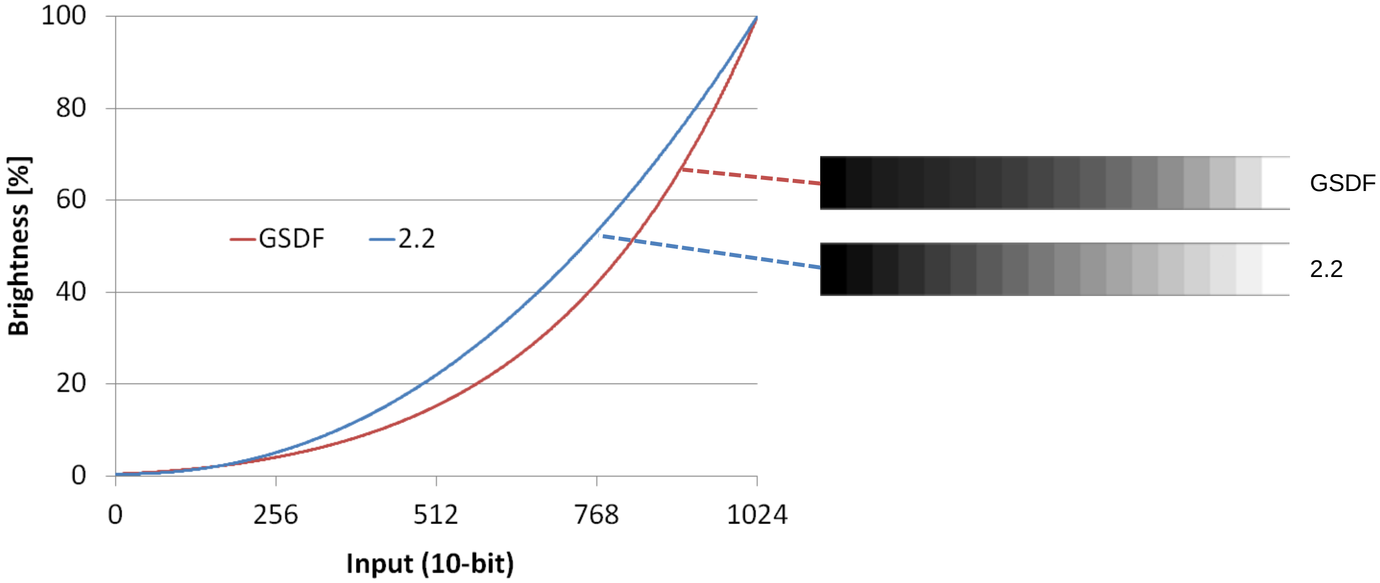

Fig. 1 Characteristics of GSDF and Gamma 2.2

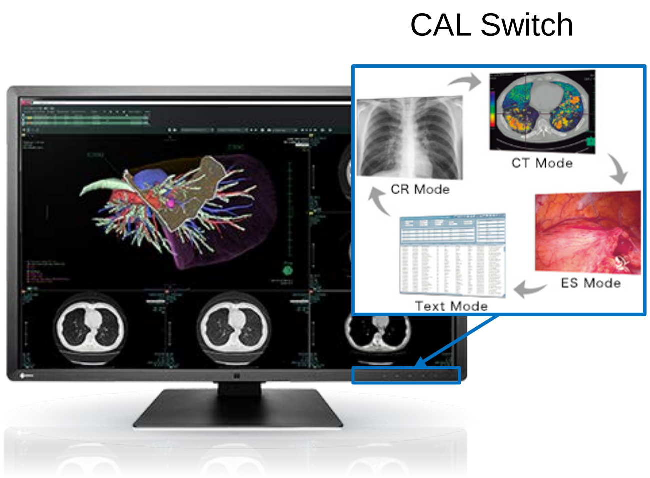

Fig. 2 Multiple modes

2 Outline of Hybrid Gamma PXL

Although traditional color medical monitors can switch between GSDF and Gamma 2.2, they are mainly used with the GSDF gamma curve due to the inconvenience of manual operation.

Therefore, there are cases where the color images are not ideally displayed. Fig. 3 shows an example of the issue. On the GSDF gamma curve, the mid tone of the color image gets darker and it might affect the readability of color images.

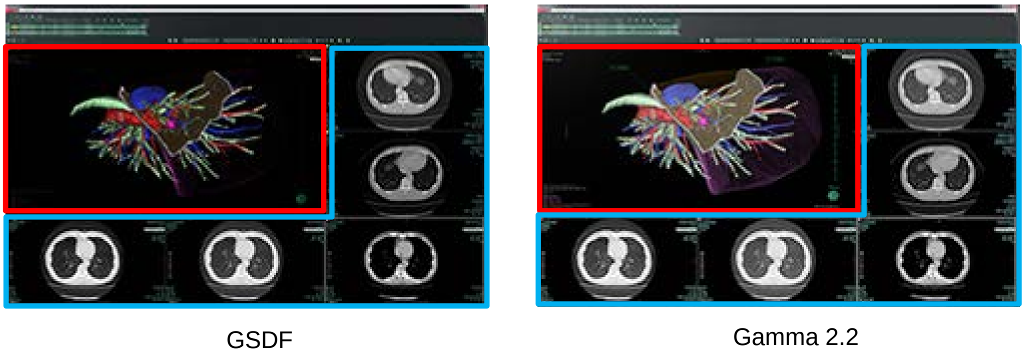

Fig. 3 Visual difference

(Blue: monochrome images, Red: color images)

The Hybrid Gamma PXL solves this problem. The Hybrid Gamma PXL detects monochrome and color pixel by pixel and assigns appropriate gamma curve characteristics in real time. This means that by enabling this function, all the monochrome pixels displayed on screen have accurate GSDF characteristics, while a "Gamma 2.2-based" curve is applied to the rest of the pixels detected as color pixels.

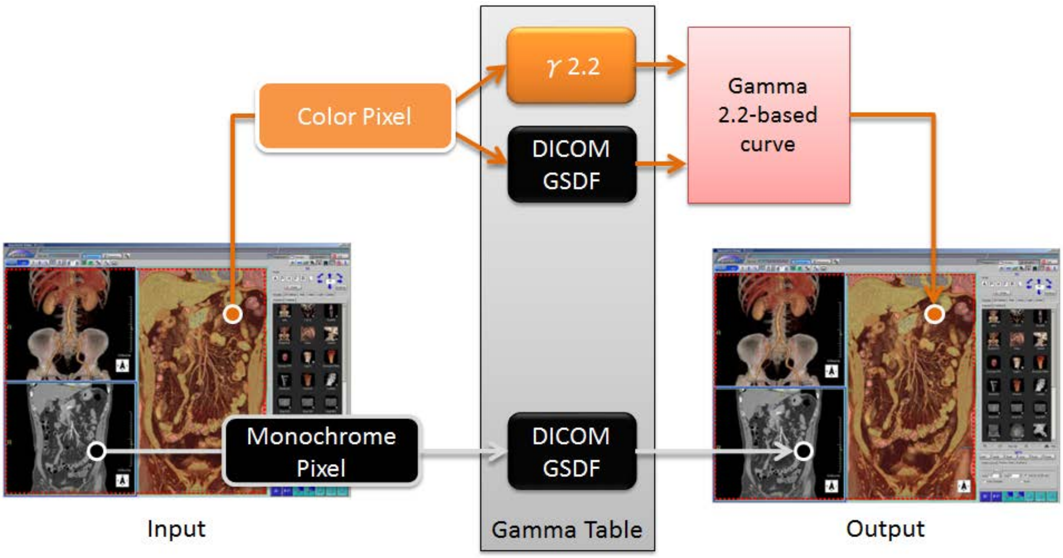

Fig. 4 Algorithm of the Hybrid Gamma PXL

On this Hybrid Gamma PXL function, this blending technique will be applied to some of the color images containing monochrome pixels, which eliminates unwanted noise effects on the color image and natural color image presentation. This white paper also validates this "gamma 2.2-based" curve used for color images.

3 Study

The goal of this study conducted by Dr. Kazuhiro Katahira, M.D., radiologist at the Kumamoto Chuo Hospital, was to assess the effectiveness and safety of the Hybrid Gamma PXL. There were three aspects of the Hybrid Gamma PXL that were assessed:

1) DICOM part 14 standard conformance on reading monochrome studies.
2) Diagnosis effectiveness of utilizing the Gamma2.2 curve on reading color studies.
3) Impact of utilizing "gamma 2.2-based" blended curve vs. true 2.2 Gamma curve.

- Period, place and subjects
  - Period : May 23, 2017 to July 3, 2017
  - Place : A reading room in Kumamoto Chuo Hospital
  - Subjects : Two radiologists with experiences of 12 and 27 years.

- Devices
  - Monitor : Two 5MP color monitors (EIZO RadiForce RX560)
    * With the settings outlined in 'Setup' below.

- Test images

Table 2 Test images

Modality		Num.	Region
Monochrome	X-ray	3	Breast, lumbus, bone
	CT	3	Head, breast, abdomen
	MRI	3	Head, spine, knee
Color	3D-CT	3	Heart, abdomen, spine
	3D-MRI	1	Heart
	MRI fusion	2	Colon, prostate
	RI	50	Cardiac muscle, brain blood flow, ect.
	ES	20	Superior division, inferior division
	US	10	Mammary gland

- Setup

Table 1 Monitor settings

Setting No.	Details
(A)	Hybrid Gamma PXL Activated (Lmin = 0.6, Lmax = 500 [cd/m^2])
(B)	Calibrated to GSDF (Lmin = 0.6, Lmax = 500 [cd/m^2])
(C)	Calibrated to Gamma 2.2 (Lmin = 0.6, Lmax = 500 [cd/m^2])

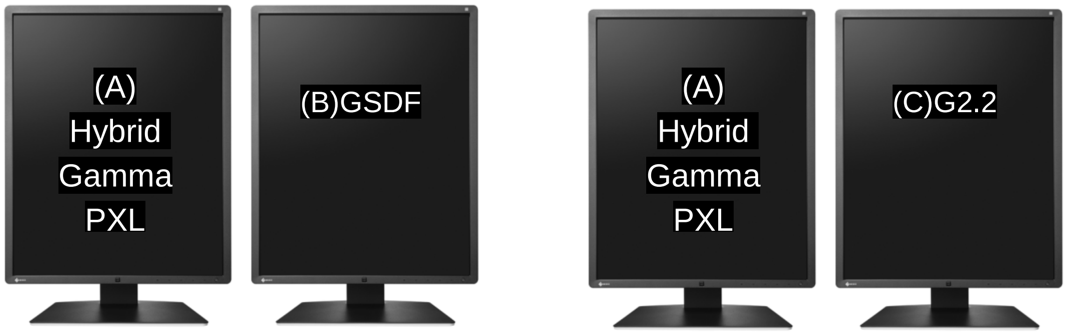

Fig 5. Combination of the monitors

- Rating method and scale

  Three alternative forced choice (3-AFC)

  (A) > (B) or (A) > (C) : (A) is better for diagnosis.

  (A) = (B) or (A) = (C) : There is no significant difference.

  (A) < (B) or (A) < (C) : (B) or (C) is better for diagnosis.

Table 3 Evaluation sheet

	Reader 1						
	(A)>(B)	(A)=(B)	(A)<(B)	(A)>(C)	(A)=(C)	(A)<(C)	Comment
Image 1 (Region, case)	1	0	0	0	1	0	
Image 2 (Region, case)	0	1	0	0	1	0	
Image 3 (Region, case)	0	1	0	1	0	0	
・・・							

- Test procedure
  1) Display a test image both on (A) and (B). (Fig. 5, Left)
  2) Choose only one out of two alternative options on (A) vs. (B) comparison
  3) Display a test image both on (A) and (C). (Fig. 5, Right)
  4) Choose only one out of two alternative options on (A) vs. (C) comparison

- Analysis

  Calculate total sum score by the following three conditions and compare the results:
  - All modalities
  - Monochrome modalities
  - Color modalities

  * The total scores are average values of the observers.

4 Results

The following graphs show the total scores of all modalities, monochrome modalities and color modalities.

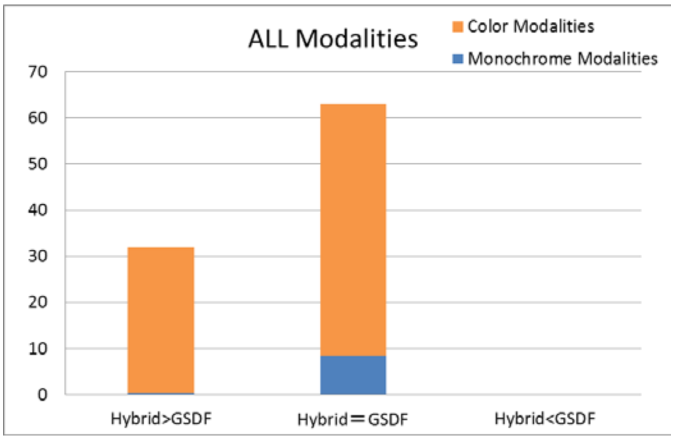

Fig. 6 Hybrid Gamma PXL and GSDF
(All modalities)

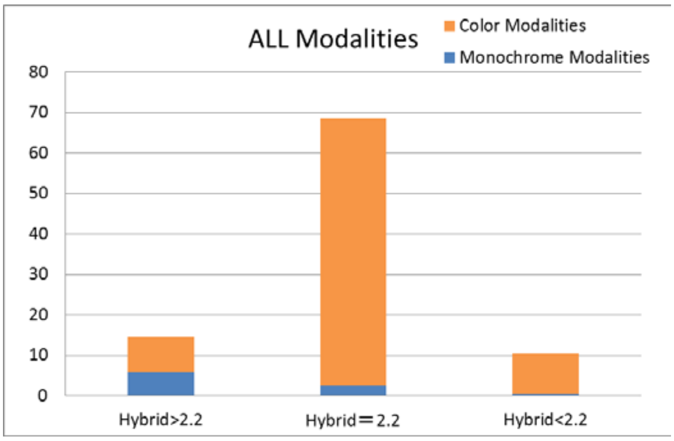

Fig. 7 Hybrid Gamma PXL and 2.2
(All modalities)

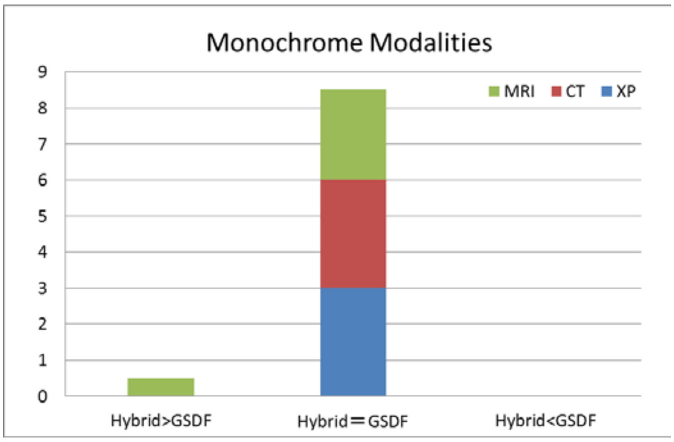

Fig. 8 Hybrid Gamma PXL and GSDF
(Monochrome modalities)

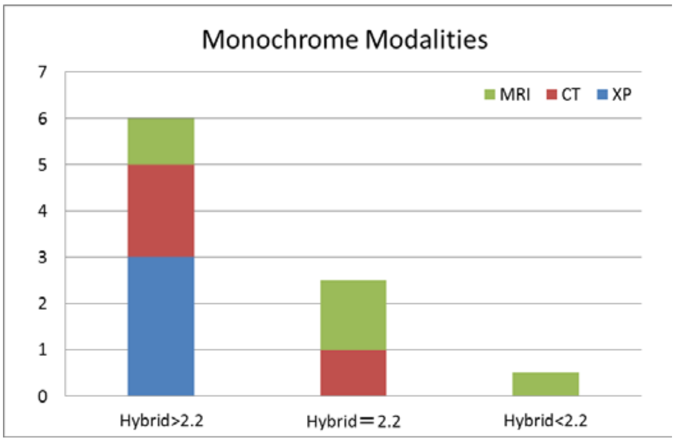

Fig. 9 Hybrid Gamma PXL and 2.2
(Monochrome modalities)

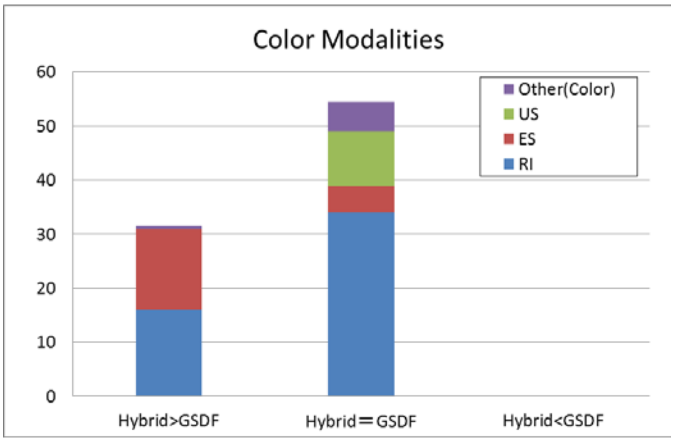

Fig. 10 Hybrid Gamma PXL and GSDF
(Color modalities)

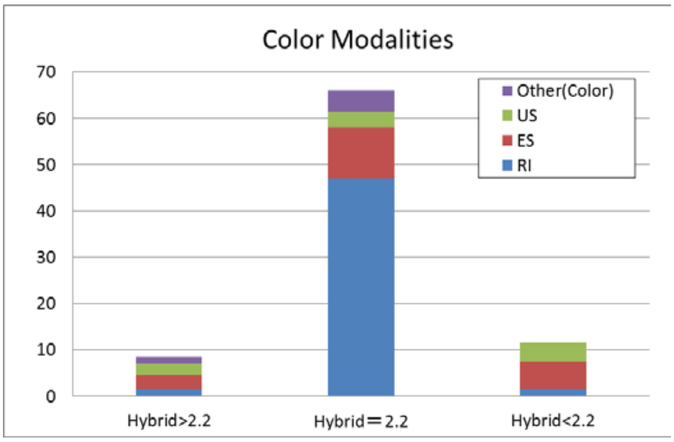

Fig. 11 Hybrid Gamma PXL and 2.2
(Color modalities)

The followings are examples of comparison images.

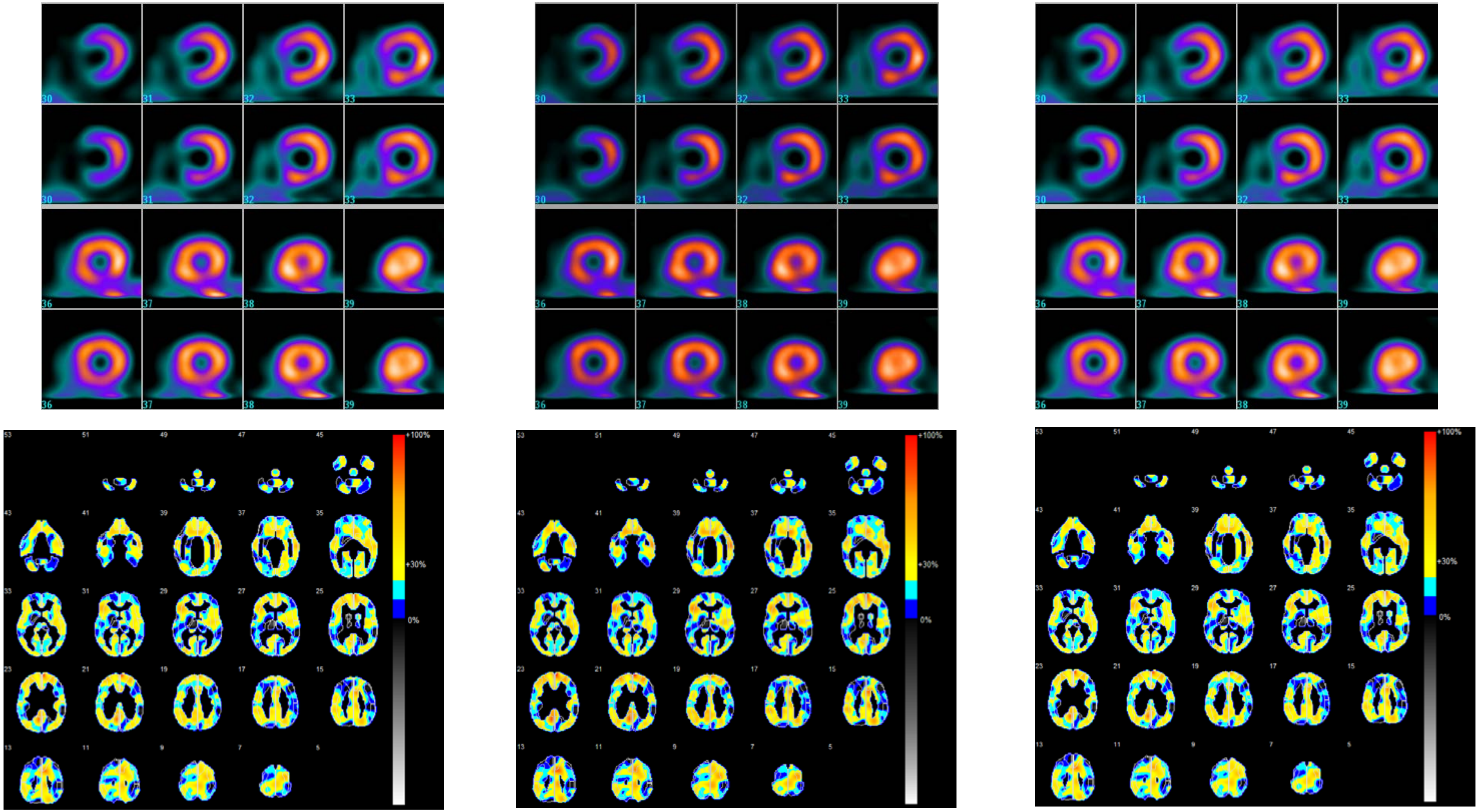

Fig. 12 Examples of RI images

(Left: Hybrid Gamma PXL, Center: GSDF, Right: 2.2)

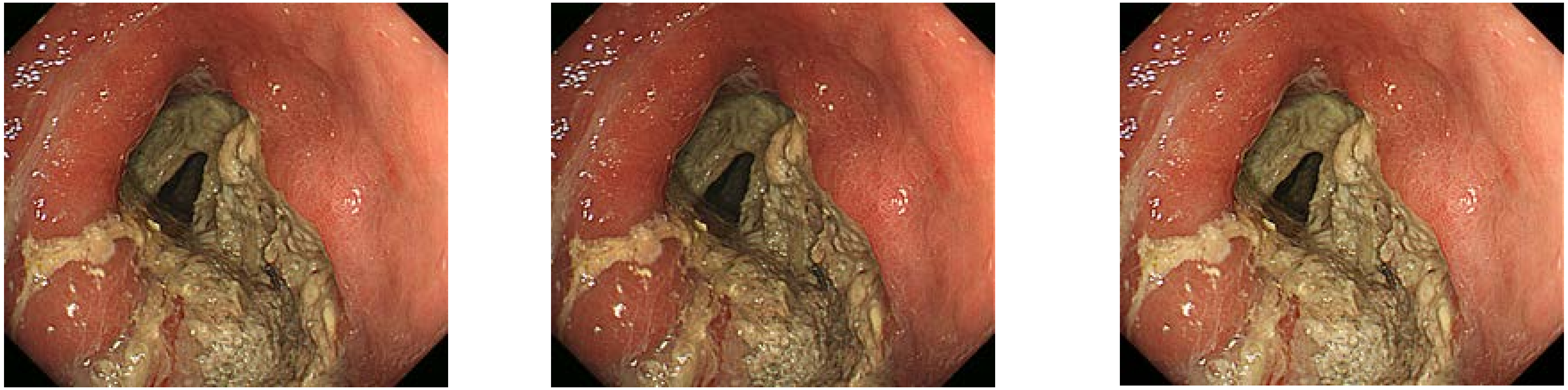

Fig. 13 Examples of ES images

(Left: Hybrid Gamma PXL, Center: GSDF, Right: 2.2)

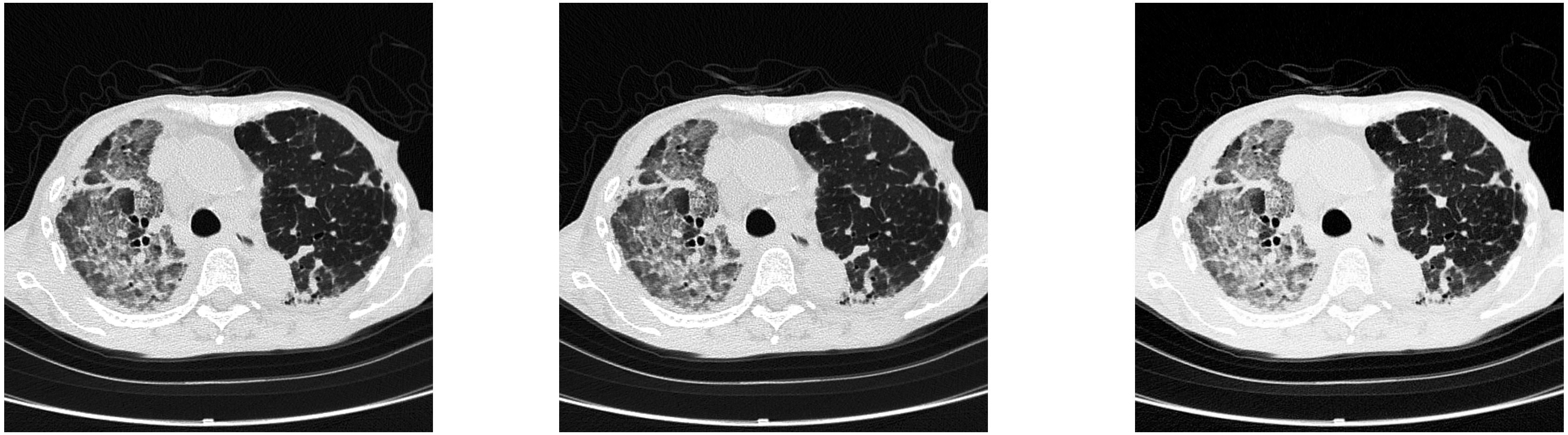

Fig. 14 Examples of CT images

(Left: Hybrid Gamma PXL, Center: GSDF, Right: 2.2)

The summaries for the three aspects are as follows.

1) **DICOM part 14 standard conformance on reading monochrome studies.**
   Fig. 8 shows that in 8.5 out of 9 monochrome image readings (about 94%), the Hybrid Gamma PXL mode (DICOM GSDF applied) is rated as equivalent to the DICOM GSDF calibrated display, and there was one case recorded where a subject rated Hybrid Gamma PXL (DICOM GSDF applied) as superior to DICOM GSDF mode. There was no case where DICOM GSDF mode was rated as superior to Hybrid Gamma PXL mode.
   As explained earlier, Hybrid Gamma PXL is designed to apply DICOM GSDF for all the monochrome pixels, this result confirms that Hybrid Gamma PXL for monochrome images is functioning properly and is performing as designed.

2) **Diagnosis effectiveness of utilizing Gamma 2.2 curve on reading color studies.**
   Fig. 10 shows that in 31.5 out of 86 color image readings (about 37%), the Hybrid Gamma PXL mode (Blended Gamma 2.2 applied) is rated as superior to the GSDF gamma curve, and these cases are either ES or RI color images, no US images. There was no case where the subjects rated DICOM GSDF as superior to Hybrid Gamma mode (Blended Gamma 2.2 applied) on color image reading.

3) **Impact of utilizing “gamma 2.2-based” blended curve vs. true 2.2 Gamma curve.**
   Fig. 11 shows that in 66 out of 86 color image readings (about 77%) the Hybrid Gamma PXL mode (Blended Gamma 2.2 applied) is rated as equivalent to the Gamma 2.2 calibrated display. In 8.5 out of 86 color image readings (about 10%), the subjects rated Hybrid Gamma PXL (Blended Gamma 2.2 applied) as superior to Gamma 2.2 mode.
   There is no negative impact by utilizing blended 2.2 Gamma curve on color image reading.

5 Conclusions

< Safety >

As confirmed on the summary (1), Hybrid Gamma PXL for monochrome images functions properly to apply DICOM GSDF to all monochrome images on screen and is equivalent to a GSDF calibrated display. This shows that the Hybrid Gamma PXL has DICOM part 14 standard conformance on monochrome images. Also from the result of the summary (3), there was no significant difference in diagnosis performance between the gamma 2.2-based curve and the true 2.2 gamma curve when reading color images.

< Effectiveness >

The result of the summary (2) revealed a significant difference (37% of total 86 color image readings) in diagnosis with the Hybrid Gamma PXL (Blended Gamma 2.2 applied) compared to the GSDF gamma curve. It indicates that reading color images with the Hybrid Gamma PXL is expected to be more effective in diagnostics than a GSDF gamma curve alone.

We conclude that the Hybrid Gamma PXL maintains the same level as DICOM GSDF conformance for diagnosis while improving color image diagnosis performance without any risk.

Reference

1. Digital Imaging and Communication in Medicine (DICOM) (2004), "Part14: Grayscale Standard Display Function", http://dicom.nema.org/dicom/2004/04_14pu.pdf
2. IEC 61966-2-1:1999, Multimedia systems and equipment - Colour measurement and management - Part 2-1: Colour management - Default RGB colour space – sRGB
   https://webstore.iec.ch/publication/6169

Note: All figures are not based on the measurement result but simplified images.