Medical Imaging Working Group

TKP Shinagawa conference center ANNEX
3 Chome-26-33 Takanawa
Minato, Tokyo, Japan
20 April 2017

Craig Revie, MIWG chair, opened the meeting at 15:00 and introduced the agenda as follows:

1. Display profile gamut and accuracy (short update)
2. Review of Medical Photography guidelines
3. Color Chart for Digital Pathology based on Color Filter Manufacturing Technology
4. Study of the impact on the difference of Color Gammas in Diagnosis of Nuclear Medicine
5. Electro-Optical Requirements for Medical Display
6. Identification of possible future projects for MIWG
7. Action items review

1. Display profile gamut and accuracy

The previous meeting had discussed the FAQ item for assessing the gamut of a display, which is at http://www.color.org/displaygamutfaq.xalter. It had been suggested that a gamutBoundaryDescType could be added as an example of encoding a display gamut using the new iccMAX gamut boundary encoding. Green reported that this had been added to the FAQ page. There had been no progress on the White Paper on display profile accuracy.

2. Review of Medical Photography guidelines

Phil Green reported that the review of the revised guidelines document had been completed, and that Dr Penczek had provided a revised version which addressed all the comments, together with a Resolution of Comments document. Jack Holm had provided extensive help in addressing the principal comment, which was the need to harmonize the recommendations with ISO 17321. The documents had been circulated prior to the meeting. In the discussion of the ROC, one further comment was made by James Vogh: since more or less all cameras now have a RAW capability, there is no need to restrict RAW capture to DSLR cameras.

The meeting agreed that with the changes to address the comment from Vogh, the document was ready for two-week ICC technical review and Steering Committee ballot.

3. Color Chart for Digital Pathology based on Color Filter Manufacturing Technology

Masahiro Yamaguchi-sensei of Tokyo Tech presented some work on WSI calibration using LCD filters [see attached]. There were two sources of variation in colour, from the device and from the staining process.

These could be addressed by colour management and a combination of chemical quality control and post-process colour correction respectively.

Toppan is the leading manufacturer of LCD filters, which are fabricated by photolithography. Yamaguchi-sensei discussed the pros and cons of the process, notably the low unit cost for large quantities. Two applications of the slide were to assess calibration accuracy and to include with a tissue slide for calibration. His group had used slides with solid filter colours and a test pattern, which gave comparable results to Yagi's calibration slide based on Roscolux filters.

Currently the slide is based on RGB filters plus three intermediate colours by dithering, and intermediate colours would need to be achieved by mixing the LCD filter colorants. The smallest patch size achieved is 20 microns, and measurements had been made at 1-2 microns. Yamaguchi-sensei invited feedback on the next step with this work, which will focus on issues such as extending the number of colours in the slide and adding a neutral patch for tone correction.

4. Study of the impact on the difference of Color Gammas in Diagnosis of Nuclear Medicine

Yusuke Bamba of Eizo presented a study of using different gamma settings for false-colour images from nuclear medicine functional imaging [see attached]. Kimpe and others had previous performed a similar analysis for pathology images, but no previous work had been published on nuclear medicine.

Bamba-san described PET and SPECT as the primary modalities in nuclear imaging. He showed examples of the false-colour colour scales used. Test images included a defective segment, and the degree of defect was ranked and compared with the original to determine the ratio of true positive to false positive. He had compared a 2.2 gamma with the GSDF and CSDF transfer functions, and found that the results varied according to the scale used as well as the gamma setting. As a result there was no single preferred transfer function of the ones tested, and he noted that gamma 2.2 is easier to achieve in practice.

5. Electro-Optical Requirements for Medical Display

Wonseon Song of LG presented a summary of technical requirements for medical displays [see attached]. She summarised trends in medical displays, and noted that LCDs are now the main focus of development, the goal being to make them thinner and improve quality parameters of luminance, contrast, bit depth, viewing angle, spatial resolution and ambient light response. The importance of low black level and local contrast for image contrast was shown.

HDR displays are becoming more important in medical imaging. LG will develop new metrics and visual assessments for medical displays. Their current experience is with television, and they are working on how to apply their expertise to the medical field.

The meeting noted that measurement parameters are defined by International Committee for Display Metrology (ICDM), part of the Society for Information Display (SID). Measurements could follow ICDM or UHD Alliance recommendations. The goal for this work is to understand the requirements for displays used in medical imaging, which could possibly be a new activity area for MIWG.

6. Possible future projects for MIWG

The meeting discussed future activity areas for MIWG. Suggestions made at the meeting were:

6.1 Viewing environment for pathology imaging (Craig Revie)
Yamaguchi-sensei noted that there was a standard in the telemedicine field, and suggested involving Dr Elizabeth Krupinski.

6.2 Automation for pathologists to detect unexpected or anomalous features using machine learning (Tom Lianza).

6.3 Colour correction for scanners (Masahiro Yamaguchi)

7. Action item review

Craig Review reviewed action items from previous meetings [see attached].
MIWG-16-05: the deadline for comment has passed, Eizo representatives will check if the document is now final or further comments are still possible
MIWG-16-07: completed
MIWG-15-30: Mr Revie will contact Tom Kimpe
MIWG-16-11: agreed to close
MIWG-16-10: Dr Vander Haeghen agreed to make a new poster which summarised the medical photography guidelines – this could be appended to the guidelines document.
MIWG-16-12: left open
MIWG-16-21: it was decided to post the liaison document in the ICC member area, and send an invitation to MIWG members to review

The meeting closed at 17:30.

Action items

The following action item was agreed at the meeting:

MIWG 17-01 Add comment from Vogh and initiate two-week technical review of Photography guidelines (Green, Penczek)

MIWG 17-02 Invite those interested in work on LCD filter-based WSI calibration to get in touch with Yamaguchi-san (Revie)

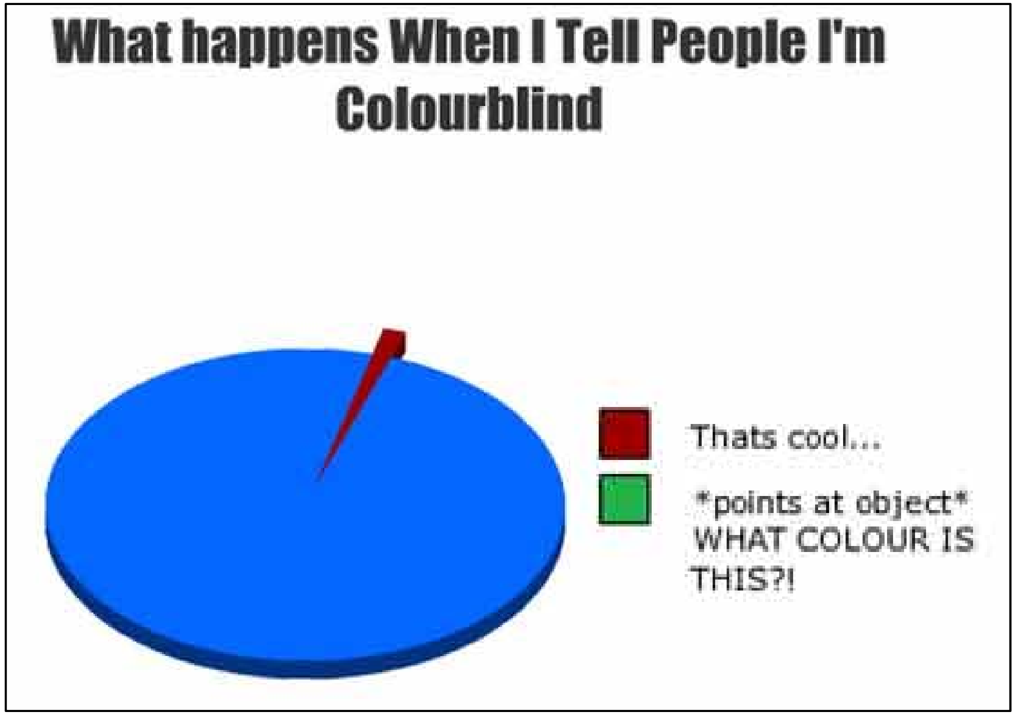
MIWG 17-03 Develop activity proposals on Viewing Environment in Pathology Imaging (Revie); Automation of Detecting Anomalous Features (Lianza); and Electro-Optical Requirements for Medical Displays (Wonseon)

ICC Medical Imaging Working Group

Tokyo

20 April 2017

Color blindness is now a laughing matter.



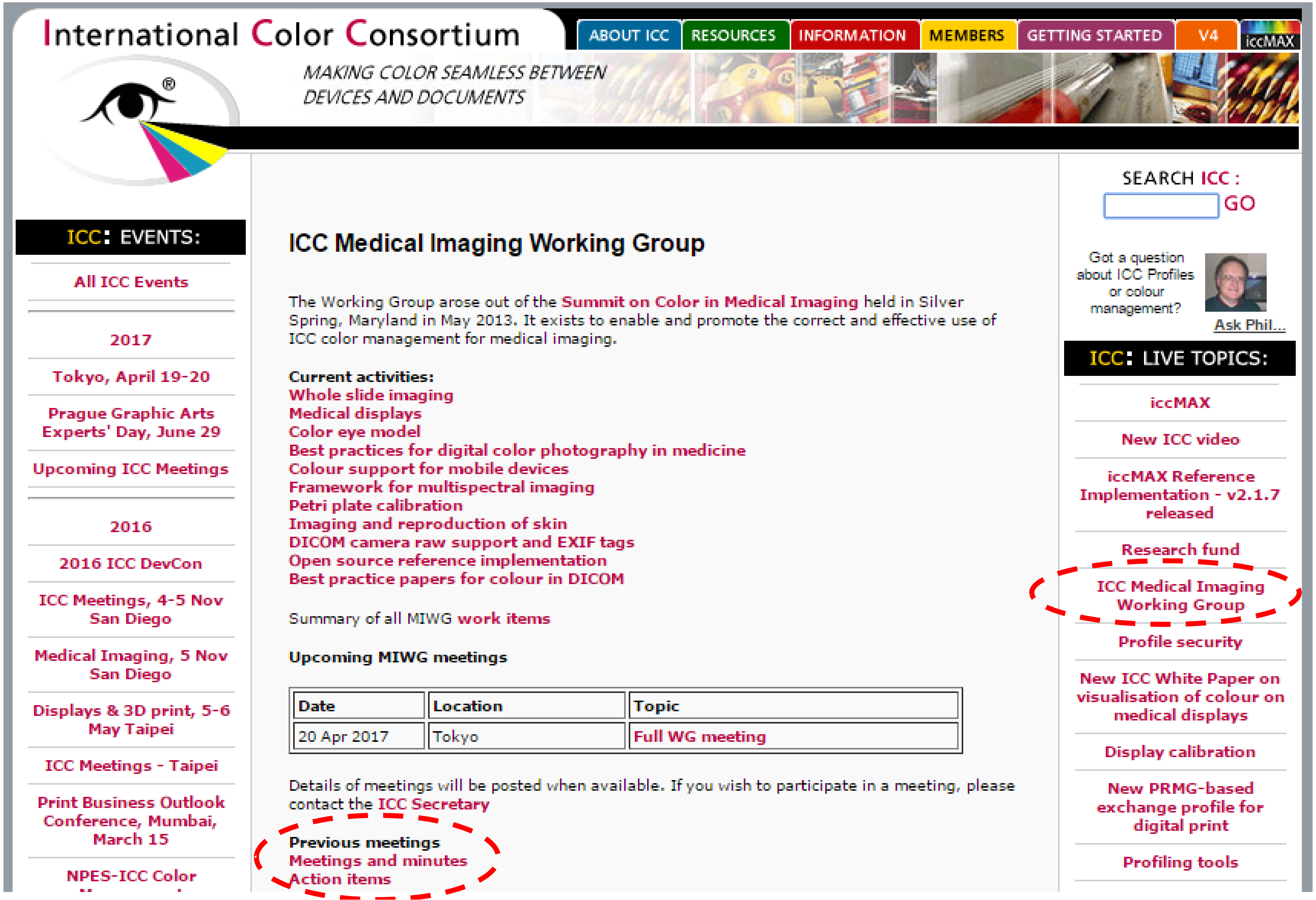
The EASA (CAA) and US FAA require colour vision testing of pilots

A number of journal articles highlight the issues for medical practitioners

Are there any official guidelines for medical practitioners?
Should there be?

International Color Consortium

ICC MIWG web page at www.color.org


International Color Consortium

ABOUT ICC | RESOURCES | INFORMATION | MEMBERS | GETTING STARTED | V4 | iccMAX

MAKING COLOR SEAMLESS BETWEEN DEVICES AND DOCUMENTS

ICC: EVENTS:

All ICC Events

2017

Tokyo, April 19-20

Prague Graphic Arts Experts' Day, June 29

Upcoming ICC Meetings

2016

2016 ICC DevCon

ICC Meetings, 4-5 Nov San Diego

Medical Imaging, 5 Nov San Diego

Displays & 3D print, 5-6 May Taipei

ICC Meetings - Taipei

Print Business Outlook Conference, Mumbai, March 15

NPES-ICC Color

ICC Medical Imaging Working Group

The Working Group arose out of the Summit on Color in Medical Imaging held in Silver Spring, Maryland in May 2013. It exists to enable and promote the correct and effective use of ICC color management for medical imaging.

Current activities:

Whole slide imaging
Medical displays
Color eye model
Best practices for digital color photography in medicine
Colour support for mobile devices
Framework for multispectral imaging
Petri plate calibration
Imaging and reproduction of skin
DICOM camera raw support and EXIF tags
Open source reference implementation
Best practice papers for colour in DICOM

Summary of all MIWG work items

Upcoming MIWG meetings

Date	Location	Topic
20 Apr 2017	Tokyo	Full WG meeting

Details of meetings will be posted when available. If you wish to participate in a meeting, please contact the ICC Secretary

Previous meetings
Meetings and minutes
Action items

SEARCH ICC : GO

Got a question about ICC Profiles or colour management?

Ask Phil...

ICC: LIVE TOPICS:

iccMAX

New ICC video

iccMAX Reference Implementation - v2.1.7 released

Research fund

ICC Medical Imaging Working Group

Profile security

New ICC White Paper on visualisation of colour on medical displays

Display calibration

New PRMG-based exchange profile for digital print

Profiling tools

ICC MIWG Working group meeting

Thursday 20th April 2017, 15:00 - 17:30

- Introductions
- Display profile gamut and accuracy (short update) — Phil Green
- Review of Medical Photography guidelines — John Penczek, Phil Green
- Color Chart for Digital Pathology based on Color Filter Manufacturing Technology — Masahiro Yamaguchi
- Study of the impact on the difference of Color Gammas in Diagnosis of Nuclear Medicine — Yusuke Bamba
- Electro-Optical Requirements for Medical Display — Wonseon Song, LG
- Identification of possible future projects for MIWG — Craig Revie
- Action items review — Craig Revie

Action items review

MIWG-14-29	Opthalmology	Provide paper on Phase 1 results for publication on ICC web site	19-06-2014	Sisson	Close
MIWG-16-01	Petri plate	Send Petri plate imaging guidelines for review by MIWG	16-02-2016	Pescatore	Open
MIWG-16-05	Displays	Provide comments on draft recommendations on display devices for radiology to Revie	16-02-2016	Martin / Nagashima-san / Bai / Kimpe / Pescatore / Vogh	Close
MIWG-16-07	Photography	Provide further input on medical photography guidelines and workflow figure to Penczek	16-02-2016	Hung	Close
MIWG-15-30	Displays	Make assessment targets available to group	13-10-2015	Kimpe	Open
MIWG-16-11	Photography	Provide document on camera calibration research project for ICC web site	04-05-2016	Vander Haeghen	Open
MIWG-16-12	Displays	Discuss ICS for GSDF and report back to MIWG	04-05-2016	Bai, Derhak, Nagashima-san, Kimpe	Open
MIWG-16-20	Petri plate calibration	Distribute draft primer on Petri plate system calibration by December 2016	05-11-2016	Pescatore	Open
MIWG-16-21	Photography	Provide liaison copy of draft ISO TR on scene-referred camera output	05-11-2016	Walowit	Done
MIWG-16-10	Photography	Provide poster on camera calibration	04-05-2016	Vander Haeghen	Open

Tokyo Tech

Color Chart for Digital Pathology based on Color Filter Manufacturing Technology

Masahiro Yamaguchi (Tokyo Tech)
Yuichiro Abe, Tetsuro Morimoto, Takaya Tanaka, Satoru Hayashibe (Toppan Printing Co.)

Acknowledgement:
We acknowledge Sakura FineTek Japan for the support in the experiment. The experiment was carried out with the students in Tokyo Tech, Shujo Ishijima and Syukran Hakim Bin Norazman.

Optical Imaging and Display Group
Yamaguchi Lab.
Tokyo Institute of Technology

Web: *http://www-oid.ip.titech.ac.jp*
E-mail: *yamaguchi.m.aa@m.titech.ac.jp*

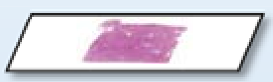
Color variation in digital pathology imaging

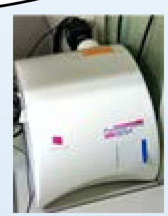
- Device dependence
  - Lamp, filter, sensor, A/D, signal processing …

  ← Color management
- Chemical process dependence
  - Fixation, staining recipe, agents, processing time

  ← Chemical process QC / Color correction

Device dependence





Different appearance

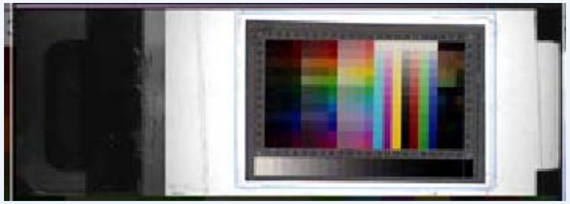
Different scanners

Different measurement

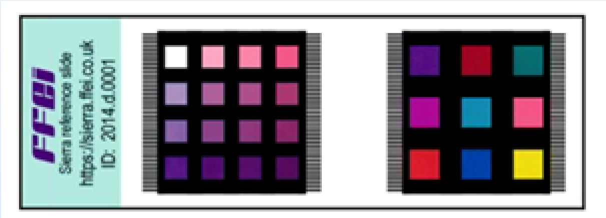
Color chart slides

- Yagi's color calibration slide

- IT8 target attached slide



- Datacolor, ChromaCal
- Sierra
  Calibration Assessment Slide



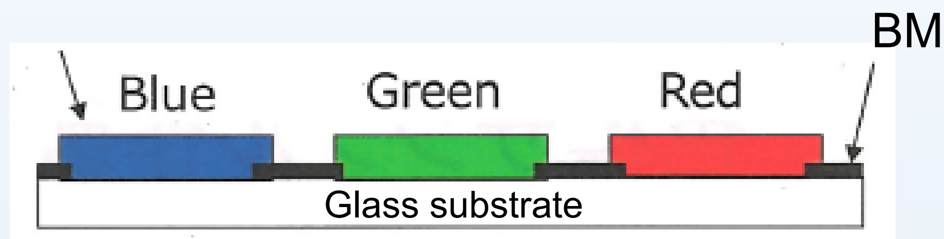
Bautista PA, Hashimoto N, Yagi Y. Color standardization in whole slide imaging using a color calibration slide.
J Pathol Inform 2014;5:4

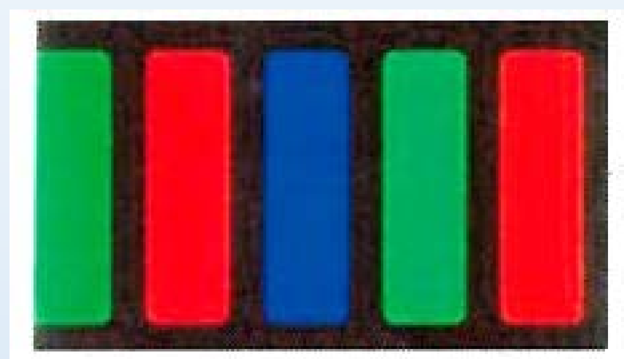
Fabrication of color chart slide

- Color on a glass slide
- Scanable
- Reliable color
- Long life-time stability
- Cost effective
- Selection of color

Color Chart based on Color Filter Manufacturing Technology

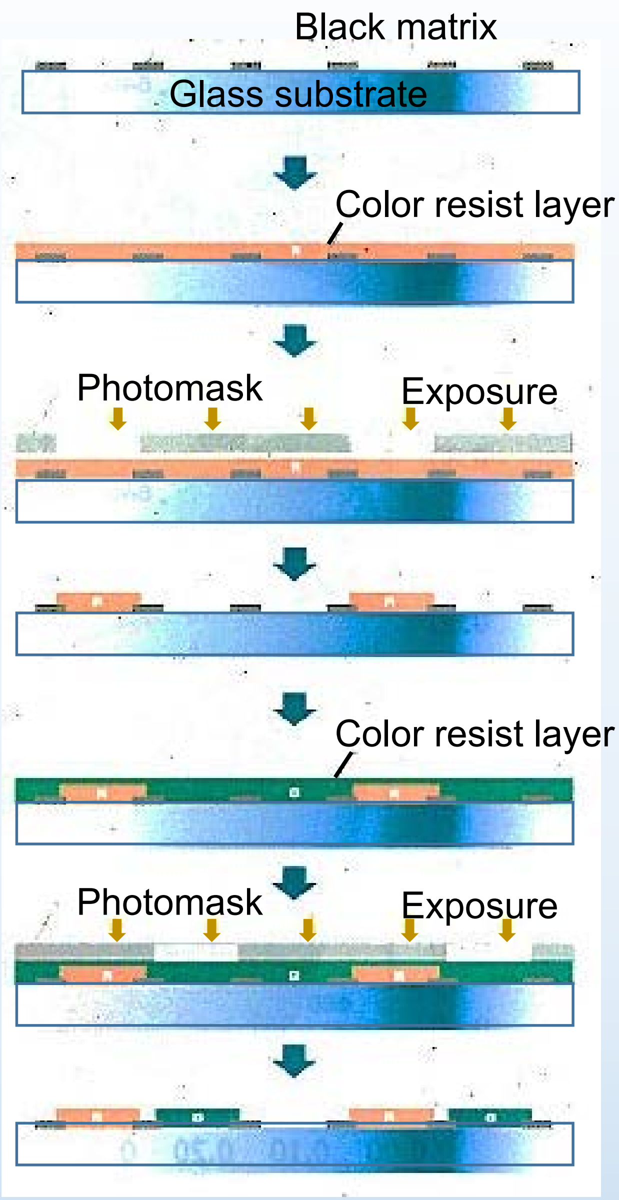
- Color filter for LCD





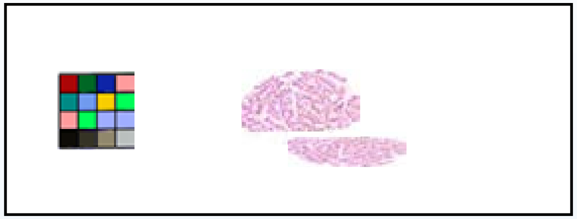
Fabrication of CF by photo-lithography

1. Black matrix
2. Red cells
   Color resist coating
   Exposure
   Development / Baking
3. Green cells
   Color resist coating
   Exposure
   Development / Baking



Color chart slide based on CF manufacturing technology

Pros / Cons



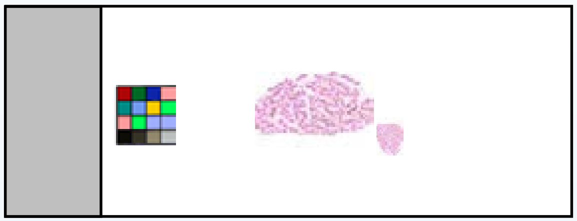
Pros

- Stable, reliable
- Low cost for mass production
- Arbitrary patterning (MTF chart?)

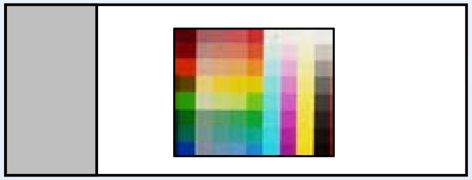
Cons

- Not suitable for small number production
- Number of colors is limited.

Possible applications



Color chart with tissue
Color calibration / assessment anytime with CF



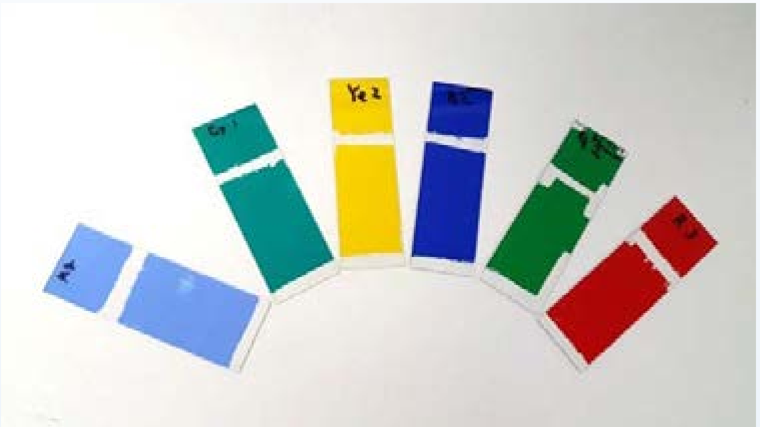
Color calibration / assessment slide for QC/QA.

Color management software

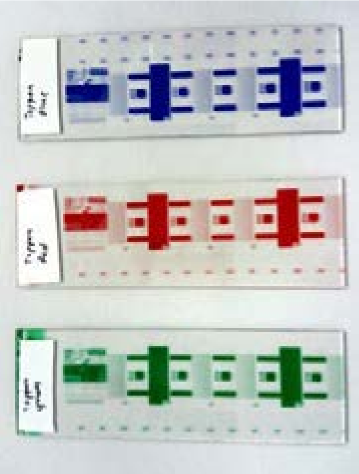
Visual assessment

Computer analysis

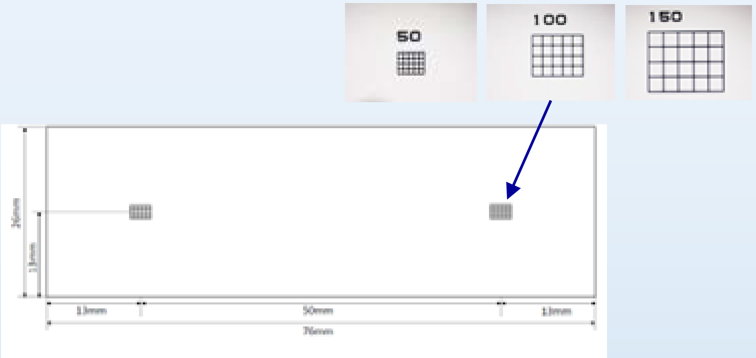
Preliminary test



Solid color slides (RGBCMY)



Test Pattern (RGB)

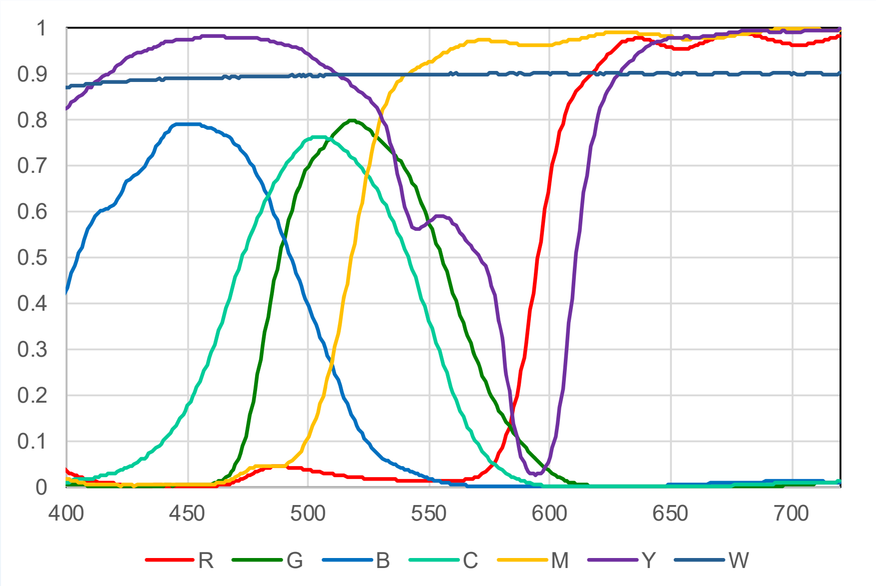


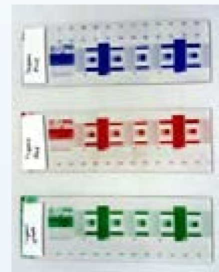
Black matrix (no color)

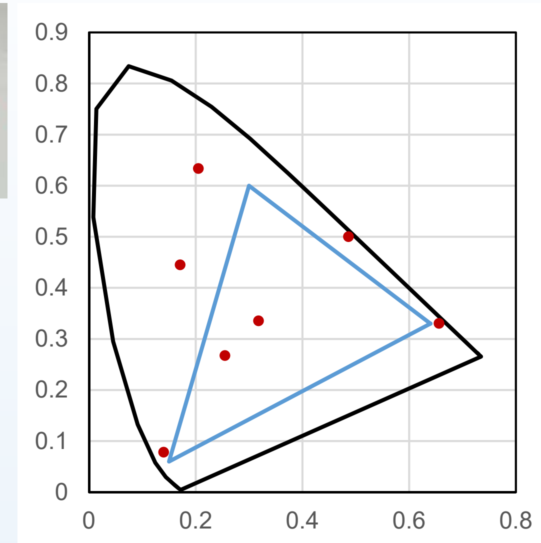
Solid gray slides

Spectral data

Toppan color calibration slide based on color filter manufacturing technology (TCF)







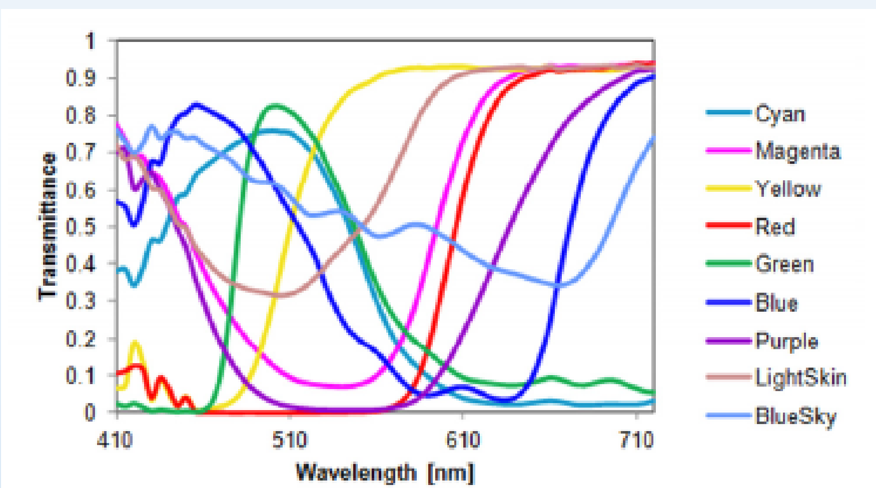


Figure 2. Spectral transmittance functions of nine color patches of MGH color calibration slide measured by spectral microscopy.

Cf. Yagi's color calibration slide (YCS)

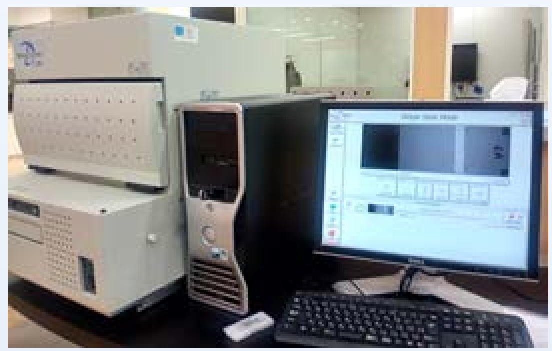
(Roscolux color filters)

Scanners

- 3D Histech Pannoramic DESK
- Hamamatsu Nanozoomer 2.0RS
- Sakura VisionTek

Reference data

- Multispectral (Varispec + BX62 + ORCA-2)



Courtesy Sakura FineTek

Evaluation

(1) Calibration performance

Is this useful for calibration?

- Calibrated by TCF is compared with other calibration methods.
- Test samples: color chart / tissue images.

(2) Assessment performance

Is this useful for calibration assessment?

- Color difference in TCF is compared with those of YCS and tissue images.

Evaluation

(1) Calibration performance

Calibration
- IT8 Target
- YCS
- TCF

→

Accuracy assessment
- YCS
- TCF
- Tissue

(2) Assessment performance

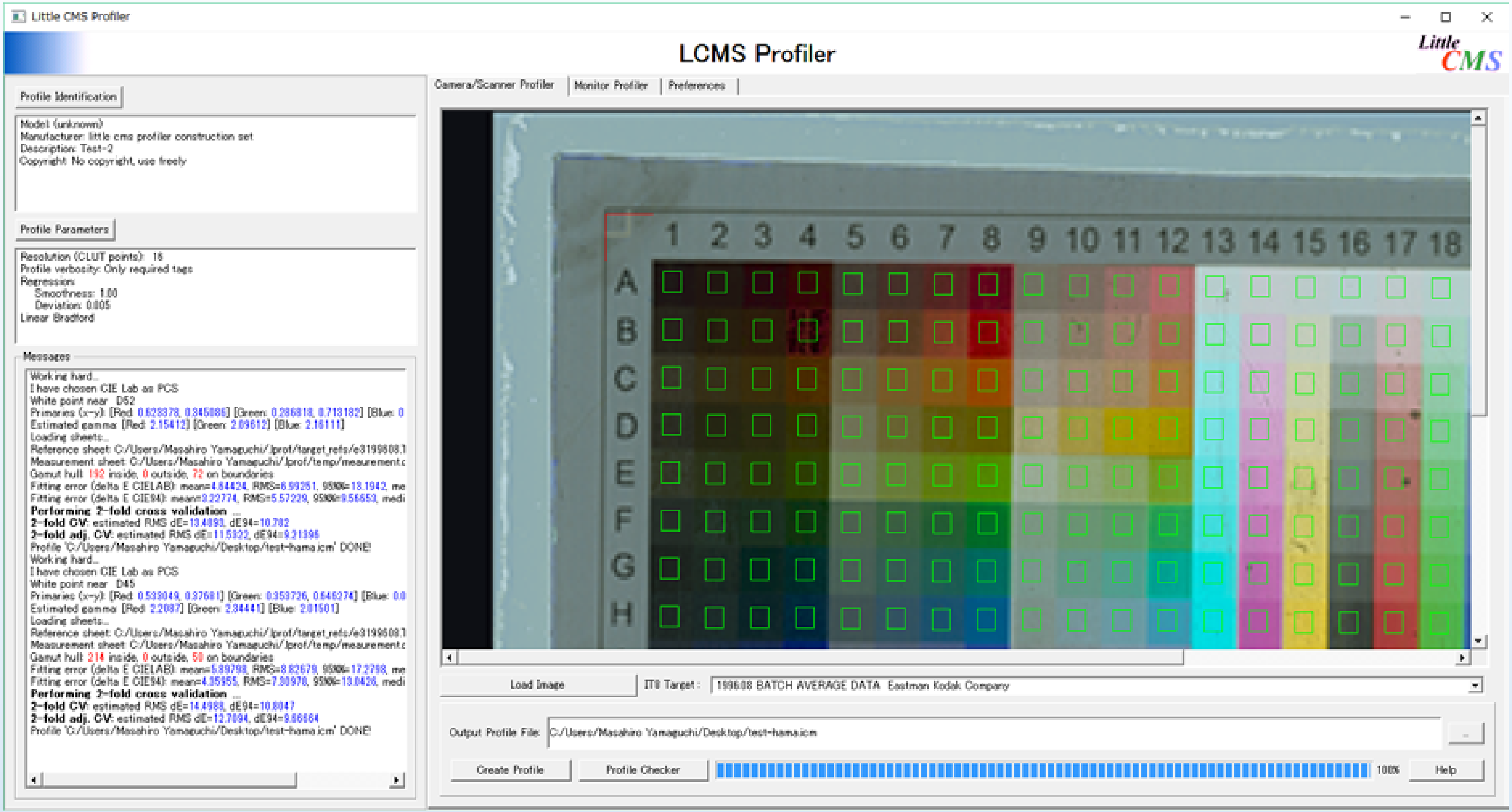
Scanner A, B, C

Calibration
- YCS

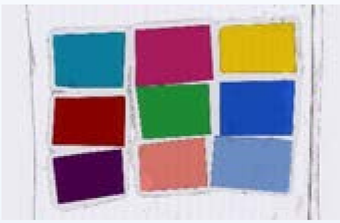
→

Accuracy assessment
- YCS
- TCF
- Tissue

ICC profile generation using IT8 target

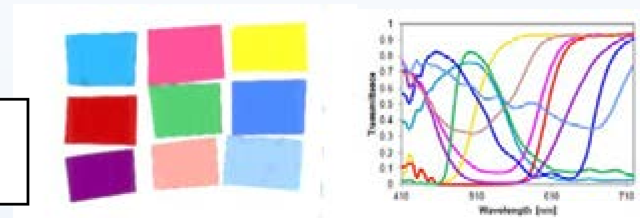


Calibration using color chart slide



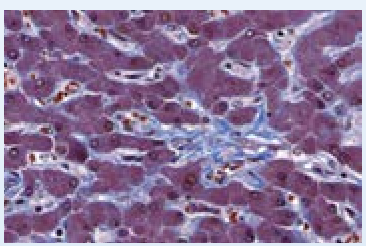
Scanned image

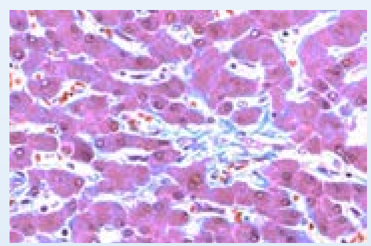
Regression



Reference data

Linear, quadratic, interaction

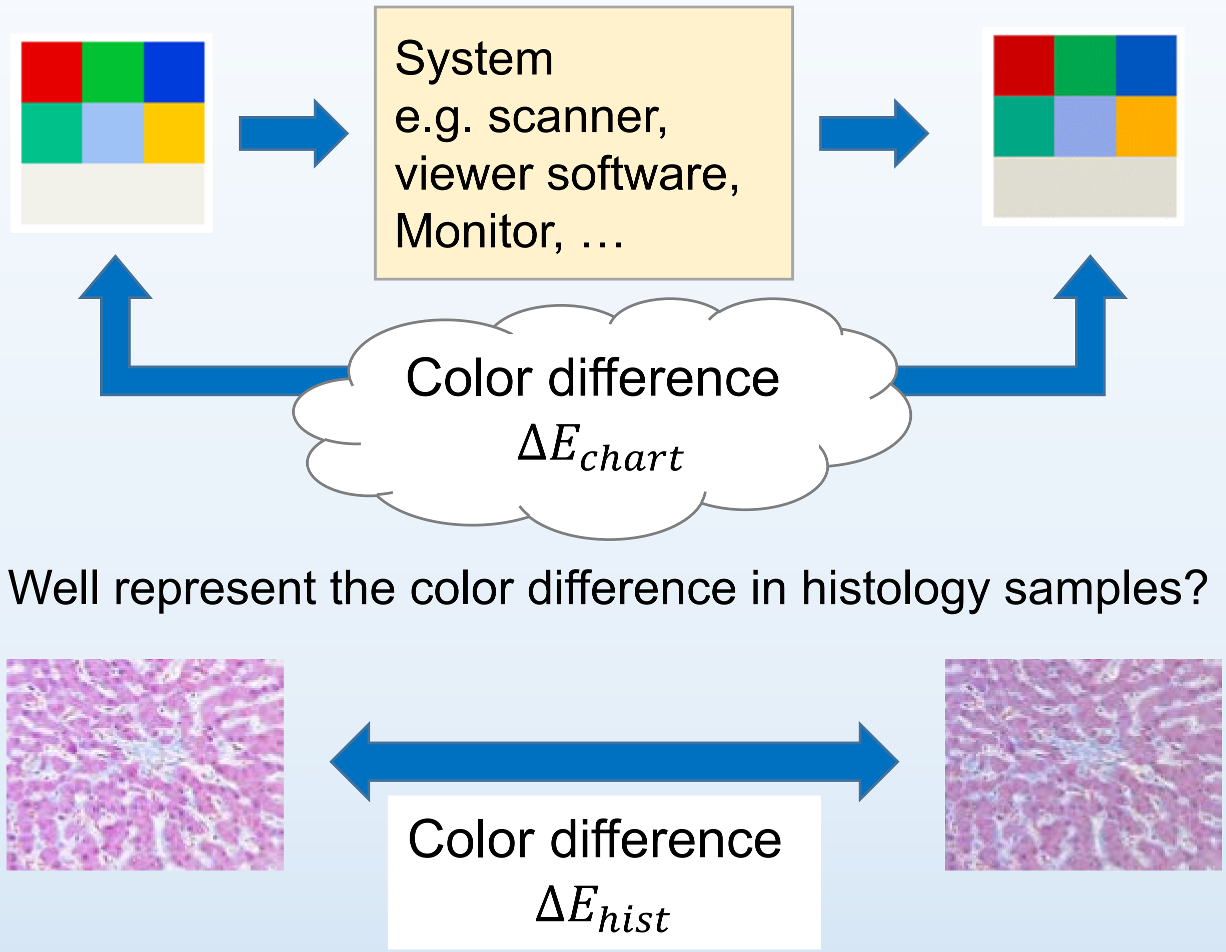


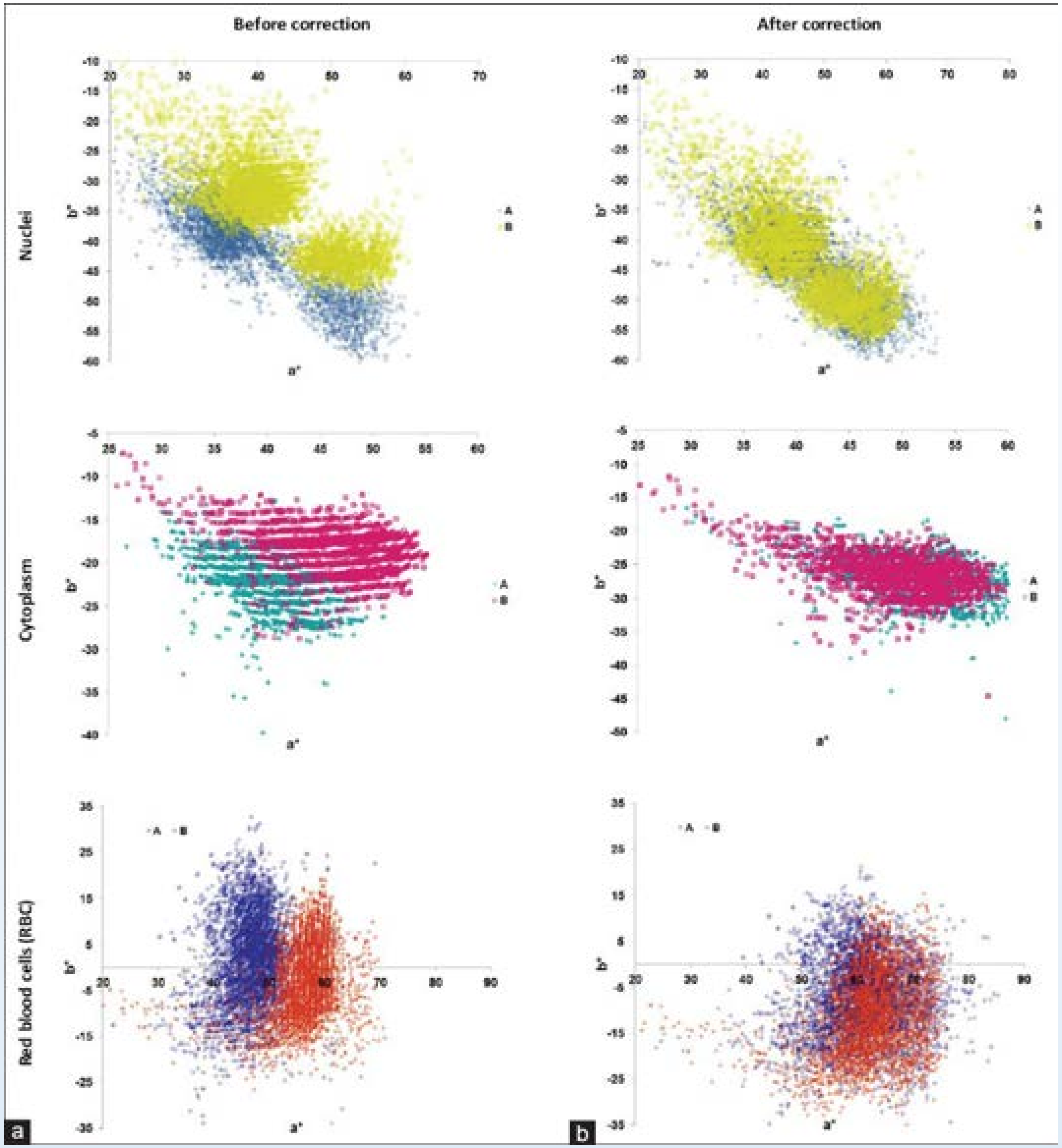


Calibrated image

Y. Murakami, H. Gunji, F. Kimura, M. Yamaguchi, Y. Yamashita, A. Saito, T. Abe, M. Sakamoto, P. A. Bautista, Y. Yagi. "Color Correction in Whole Slide Digital Pathology," Proc. of 20th CIC, pp. 253-258, 2012.
Bautista PA, Hashimoto N, Yagi Y. Color standardization in whole slide imaging using a color calibration slide. J Pathol Inform 2014;5:4

Assessment using color chart slide

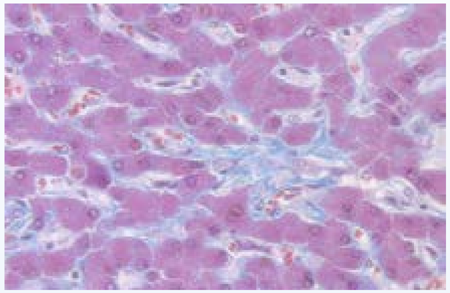




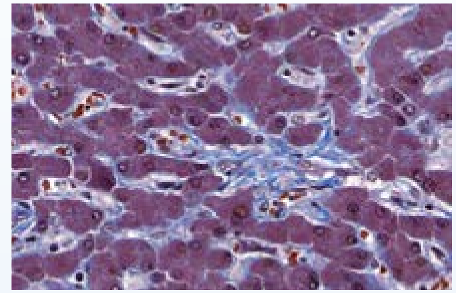
Bautista PA, Hashimoto N, Yagi Y. Color standardization in whole slide imaging using a color calibration slide. J Pathol Inform 2014;5:4

Color difference between images captured by different scanners is evaluated using Jeffrey divergence of color histogram.

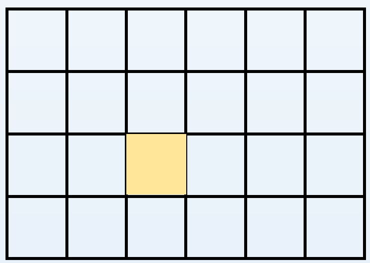
Reference image

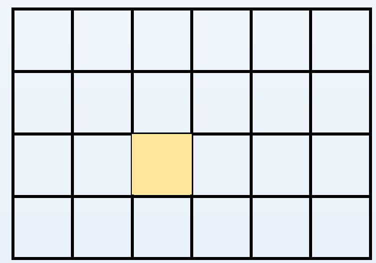


Test image



Divide into small blocks





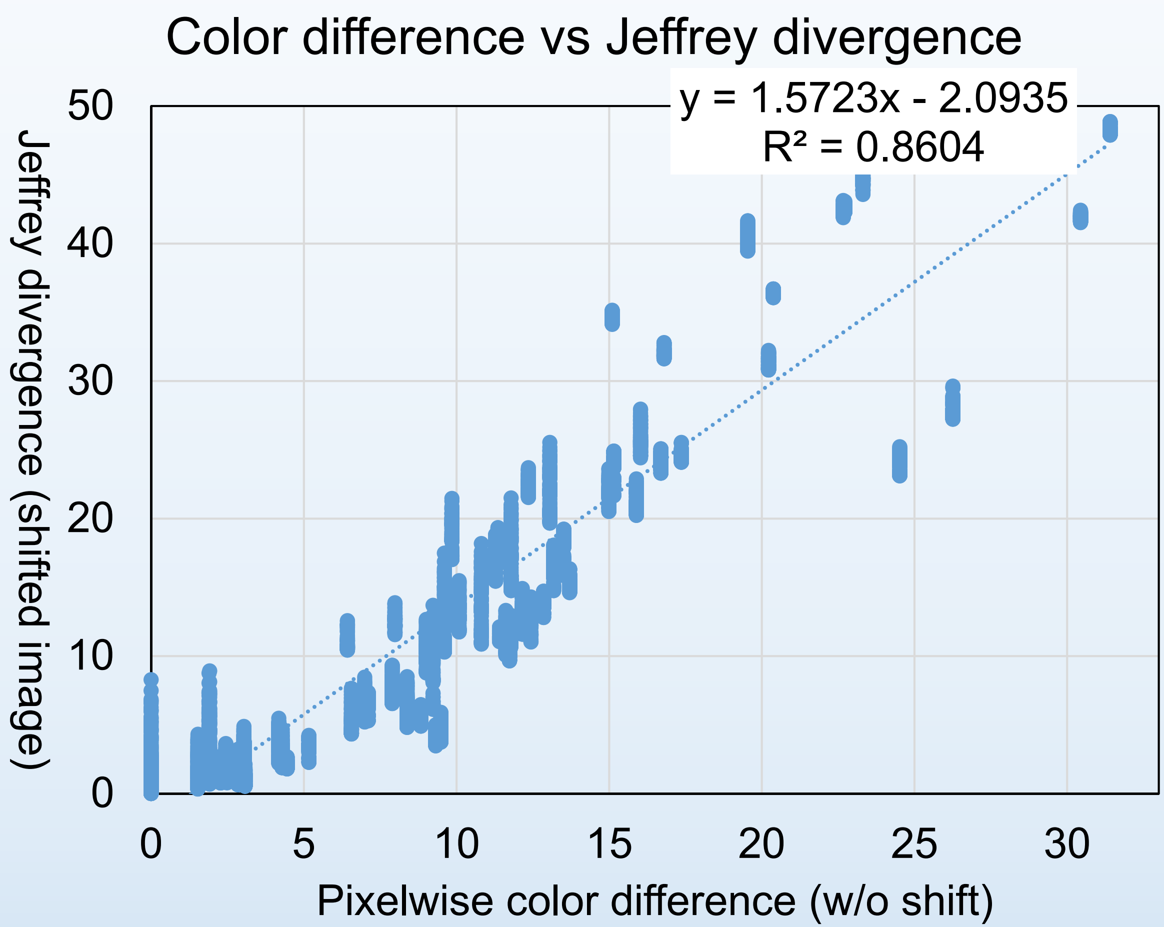
Histogram in L*-a*, L*-b*, a*-b* planes (w Gaussian filtering)

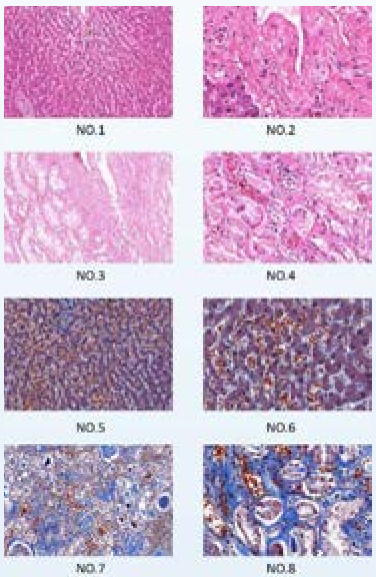
Histogram difference
(Jeffrey divergence)

Image color difference is approximated by

Image_DE := (JD_avg.*100+2.0935) ./ 1.5723;

Does JD correlate with ΔE ?





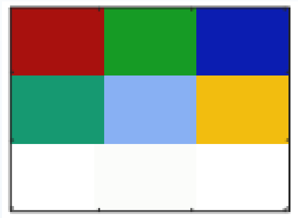
Test images

Jeffrey divergence is calculated after shift, magnification, and rotation.

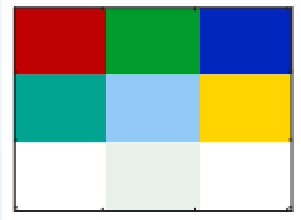
Calibration performance

Calibration

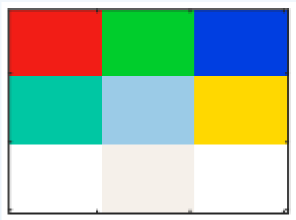
- IT8 Target
- YCS
- TCF

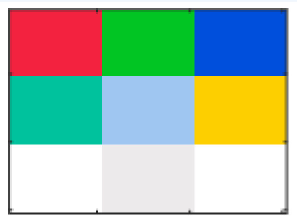

Scanned


Reference


IT8 target


YCS linear

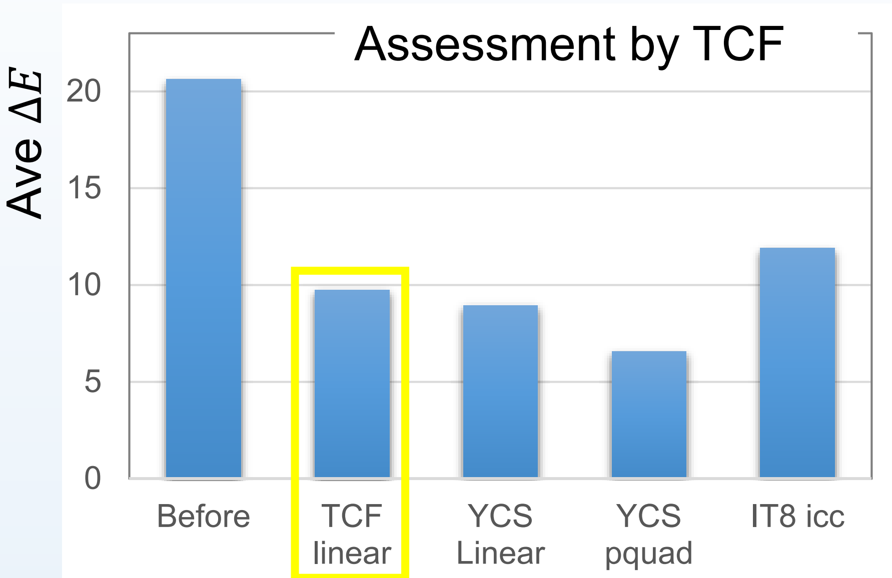

YCS quad

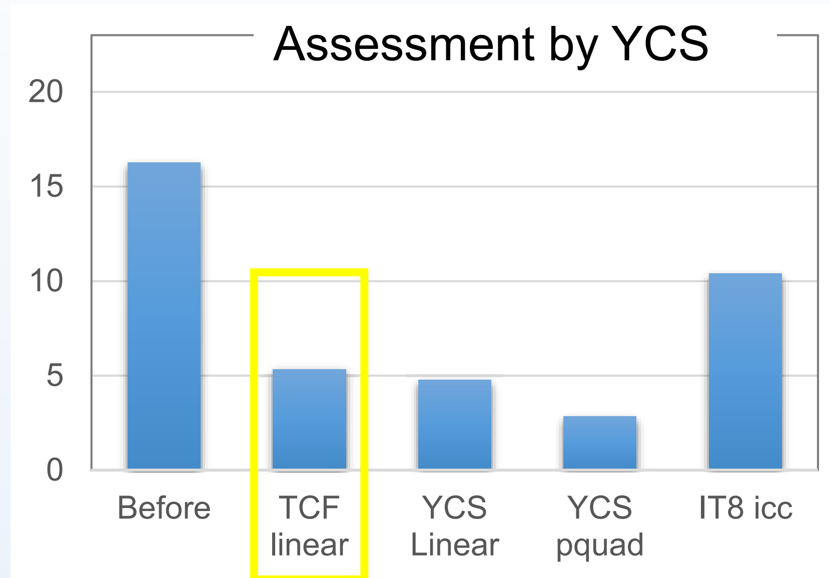

TCF linear

Accuracy assessment

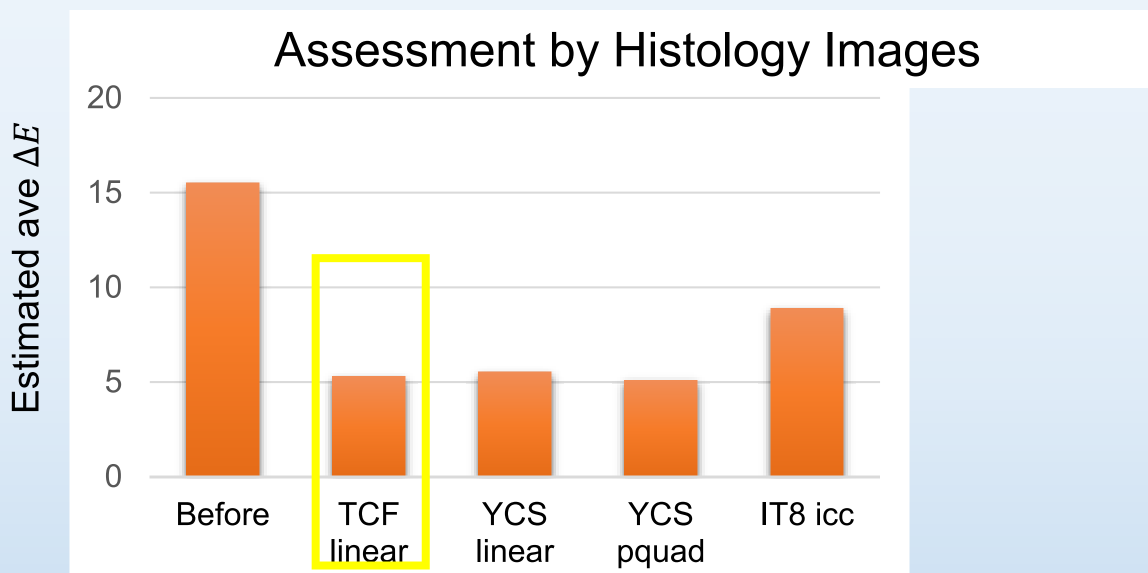
- YCS
- TCF
- Tissue

Result of calibration performance

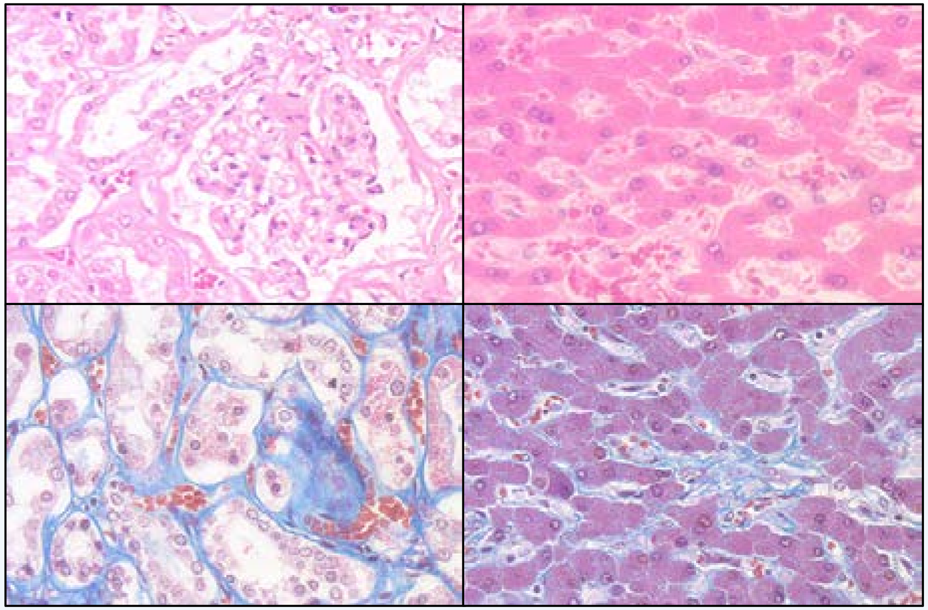




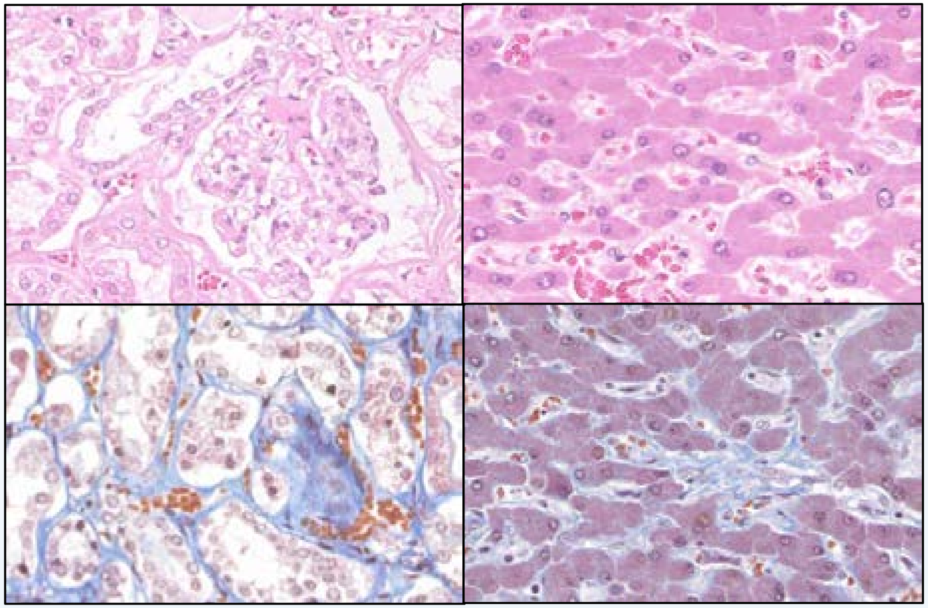
Scanner A



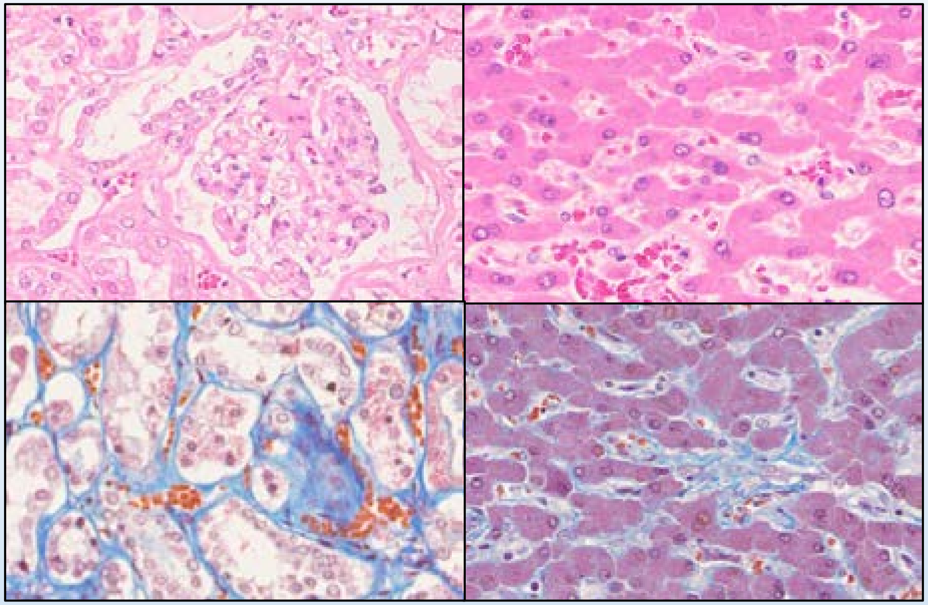
gamma



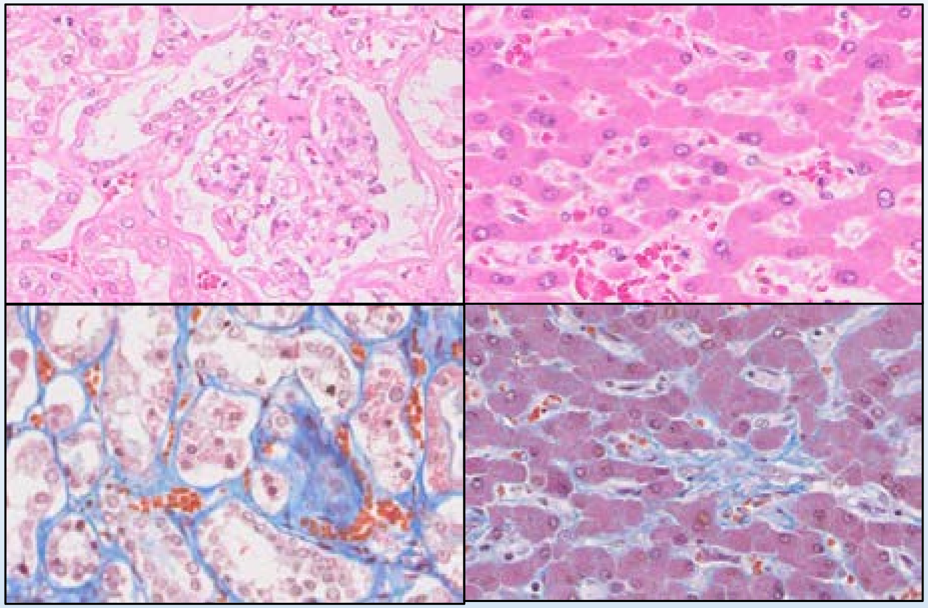
Reference



Scanner A

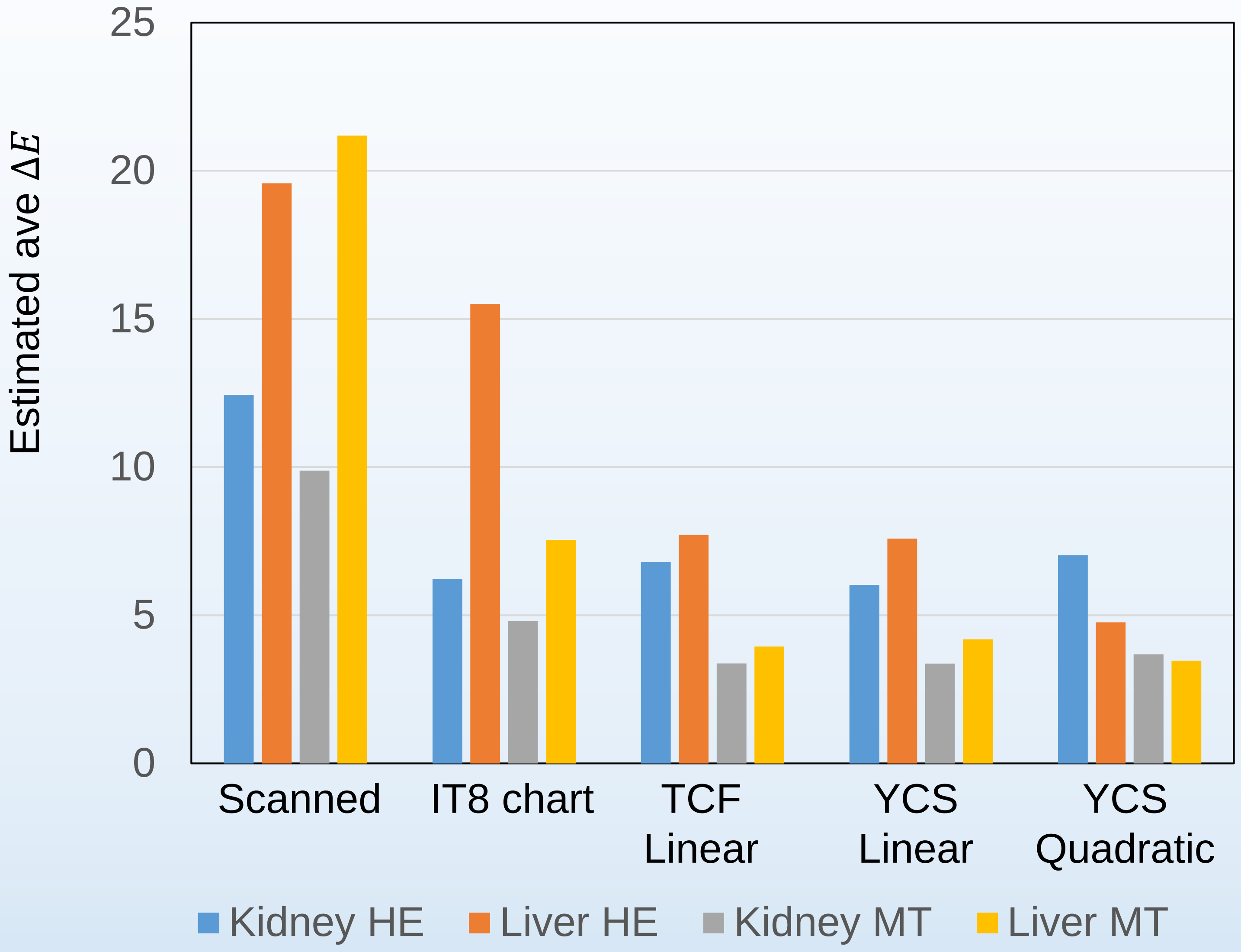


YCS Quadratic

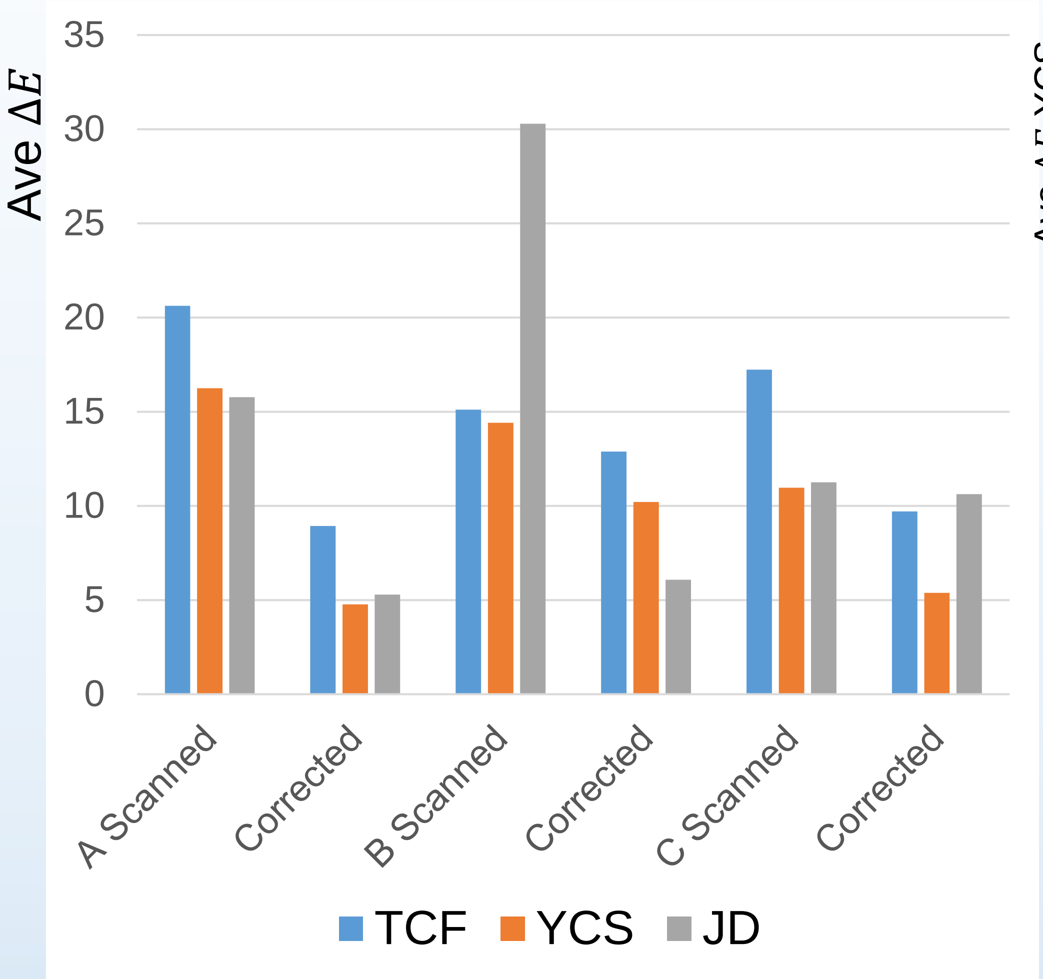


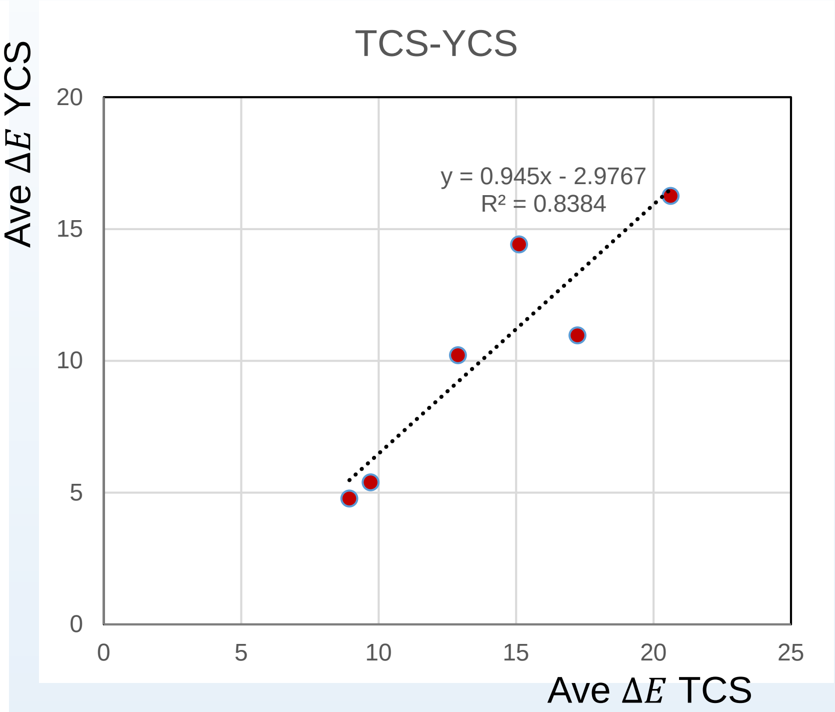
TCF Linear

JD results for 4 images



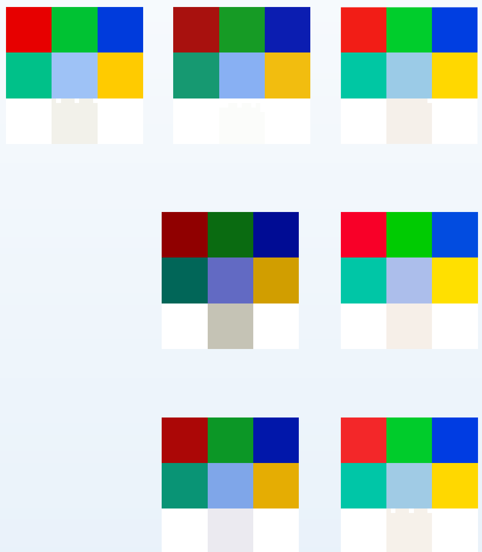
Assessment performance

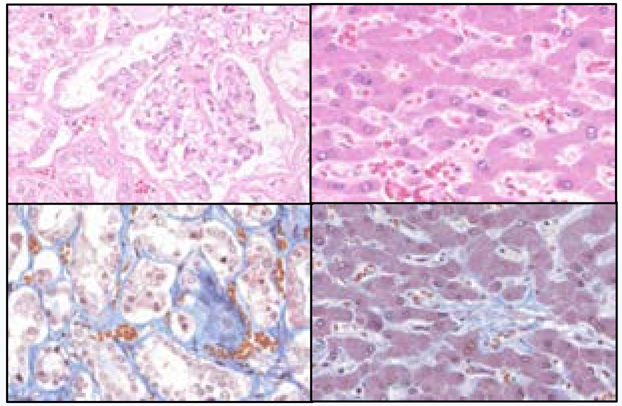




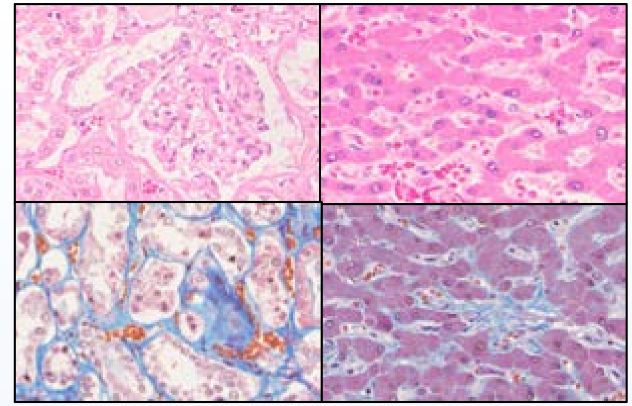
Naturally, the performance is almost consistent with YCS.

Comparison of before and after correction (YCS quadratic).

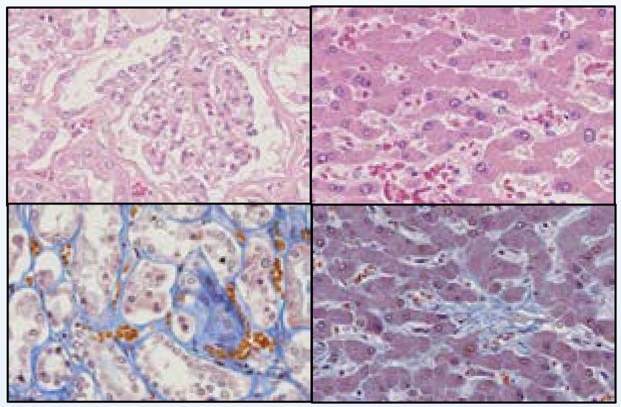




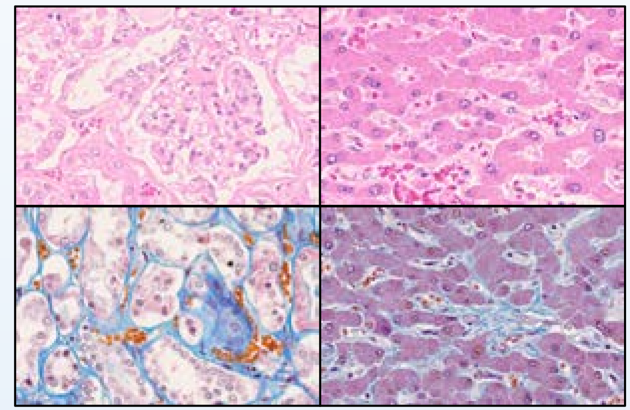
Scanner A



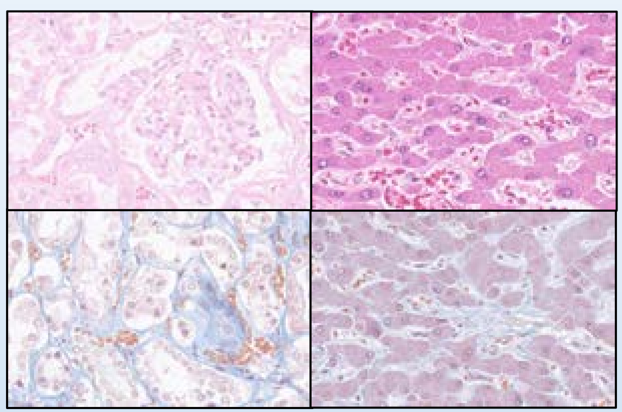
Corrected



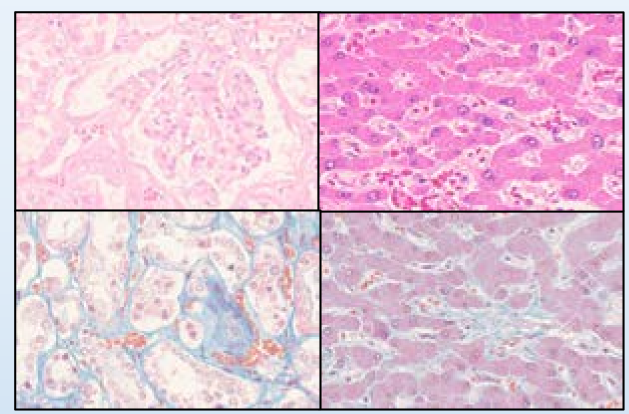
Scanner B



Corrected



Scanner C



Corrected

Summary of results

- Similar results with YCS.

  Both calibration and assessment.
- Number of colors are limited.
- Some colors are out of sRGB gamut.
- Some difficulties in scanning process.
  - Tissue detection
  - Focusing

Conclusions / Future issues

- **CF manufacturing technology is reliable and stable process for fabricating color chart slides.**
- **Usable for both calibration and assessment.**

▸▸ Future issues

- Fabrication of a real color chart slide.
- Tone curve correction using gray patch.
- Improvement of color selection.
- Consistency with the color difference in stained tissue images
- Scanning problems.
- Technology for increasing the number of colors.

- Business issues.

Your feedback is necessary for next step.

Web: *http://www-oid.ip.titech.ac.jp*
E-mail: *yamaguchi.m.aa@m.titech.ac.jp*

The Study of the impact for the difference among Color Gammas in Nuclear Medicine Field

Yusuke Bamba[1], Shinji Saito[1],
Masahisa Onoguchi[2], Takayuki Shibutani[2],
Kenichi Nakajima[2], Hiroto Yoneyama[3]

1: EIZO Corporation
2: Department of Quantum Medical Technology, Kanazawa University
3: Department of Nuclear Medicine, Kanazawa University Hospital

Background & Purpose

	dRGB	ACR (Reference)	sRGB (Reference)	AdobeRGB (Reference)
Luminance Response	DICOM GSDF	DICOM GSDF	~2.2 power function	2.199 power function
Color Gamut	**[*under discussion]**	-	HDTV based ITU-R BT.709-5	'Wide' (extended G)
L_{max}, cd/m^2	350 (250-450)	350/420/250	80	160 (125-200)
L_{min}, cd/m^2	L_{max} / LR	L_{max} / LR	-	0.56
Luminance Ratio (LR)	350 (300-400)	350 (> 250)	-	287.9 (230-400)
White Point	D65	D65	D65	D65
Gray tracking	IEC MT51	-	-	-

Validity + **Consistency**

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Background & Purpose

- A study of the impact for the difference among display gammas in digital pathology was carried out by Barco before[1].

- No similar study in nuclear medicine which uses pseudo colors has been carried out yet.

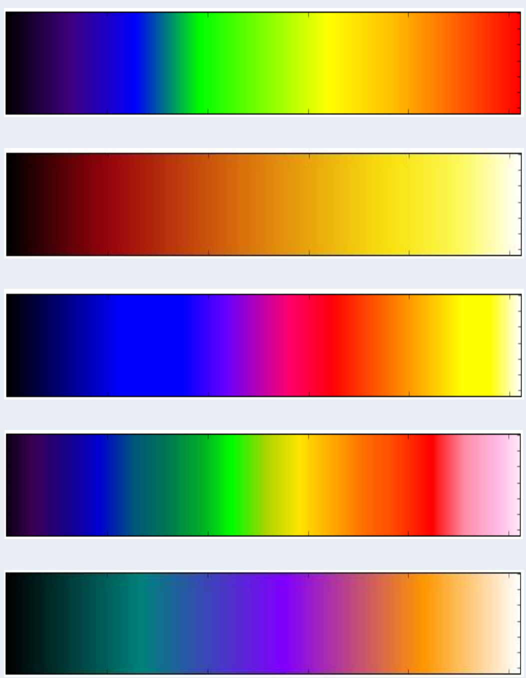
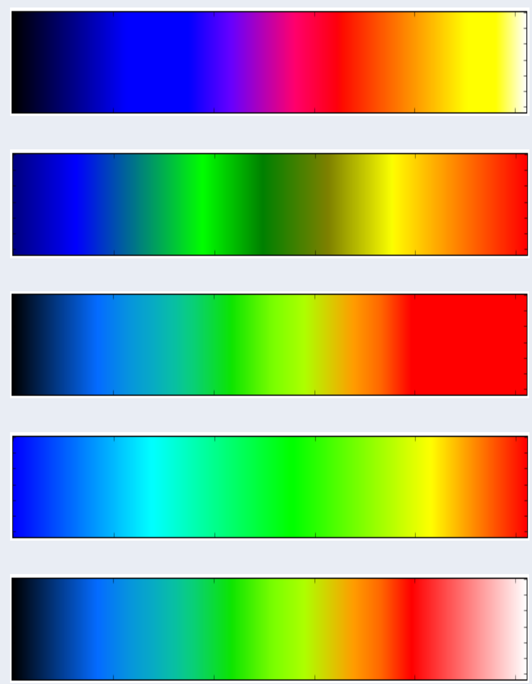
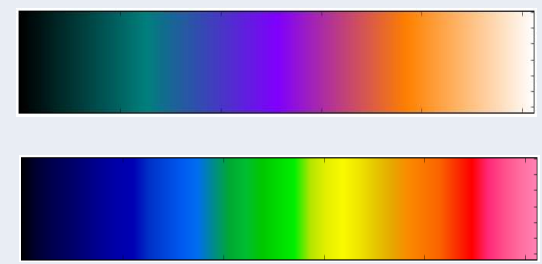
- We studied the impact for the difference among display gammas in nuclear medicine field with Kanazawa University.

1) T. Kimpe, *Does the choice of display system influence perception and visibility of clinically relevant features in digital pathology images ?*
2) , SPIE Medical Imaging 2014

SPECT/PET

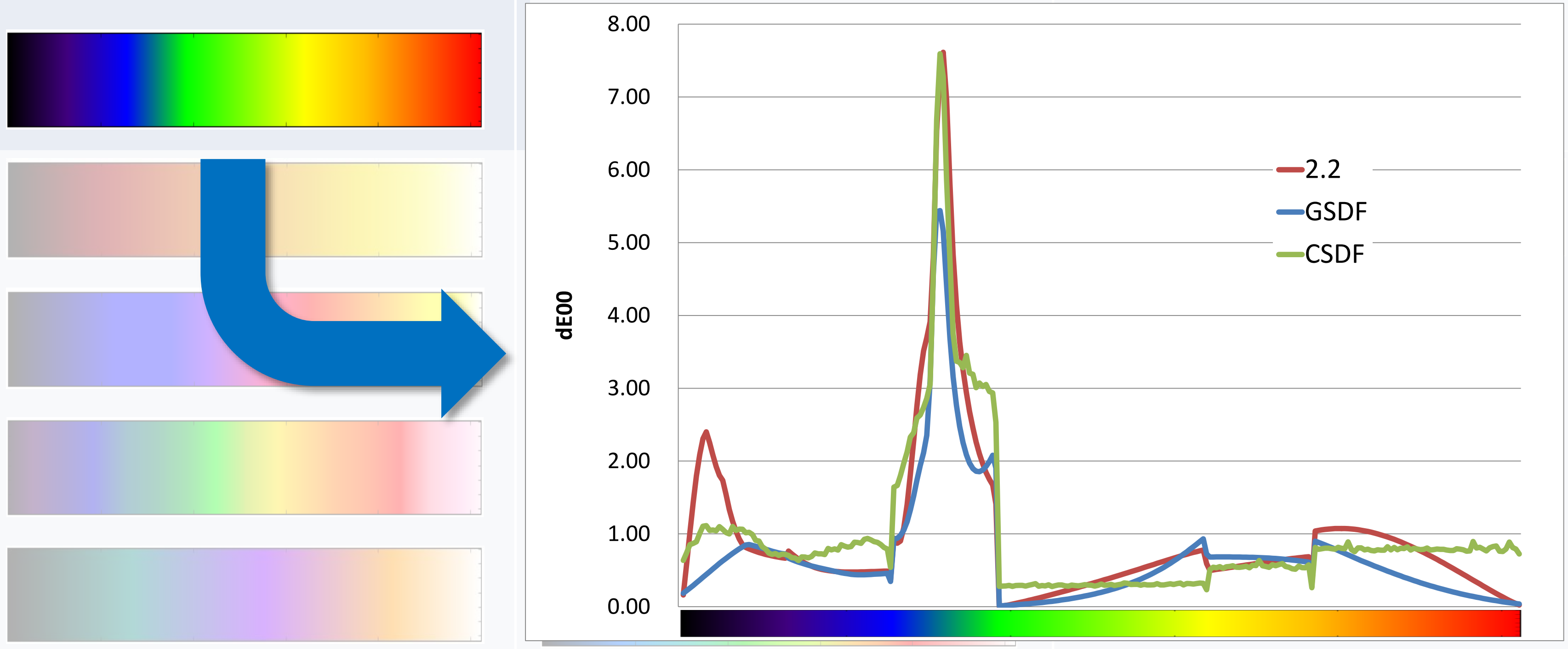
- SPECT/PET
  - Outline
    - Single Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET) are nuclear medicine functional imaging methods using gamma rays. Gamma-emitting radioisotopes are administered into a patient. SPECT/PET scanners detect the distribution and emissions of gamma rays and reconstruct it into 2D/3D images.
  - Application
    - Myocardial perfusion image
    - Cerebral blood flow image

Various Color scales

SIEMENS	TOSHIBA	GE
		

Various Color scales

SIEMENS	TOSHIBA	GE



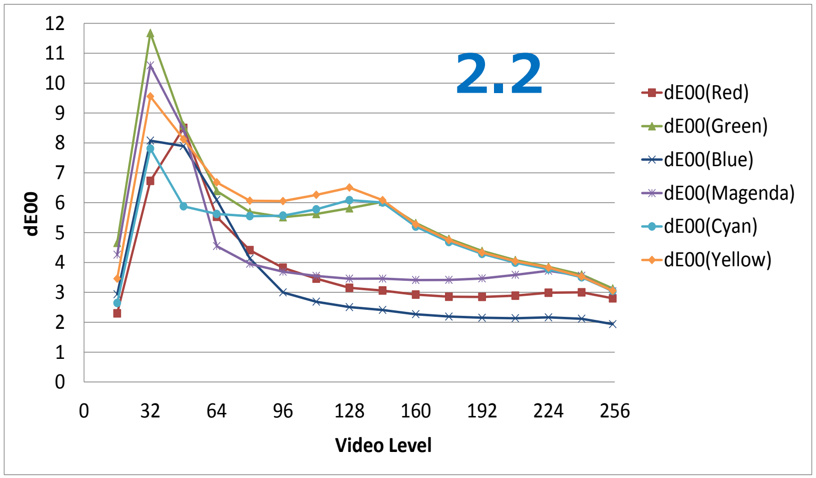
Experimental Condition

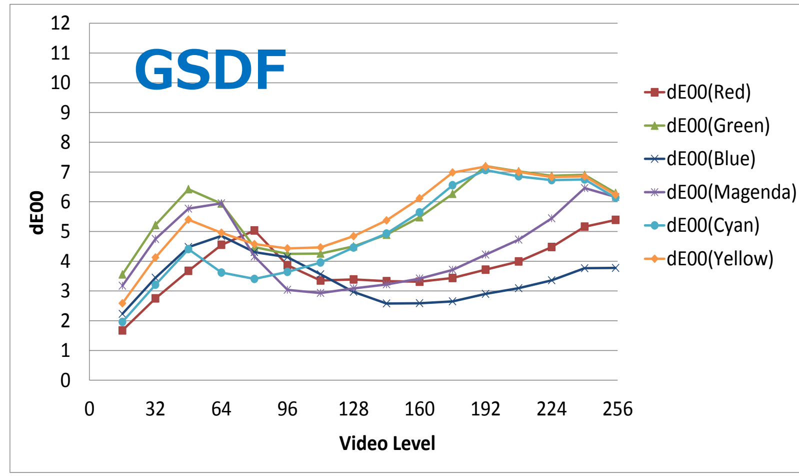
- LCD display
  - EIZO ColorEdge CG318-4K
  - Display gamma 2.2, GSDF and CSDF
- Observers
  - 2 Radiologists
  - 3 Radiology technologists

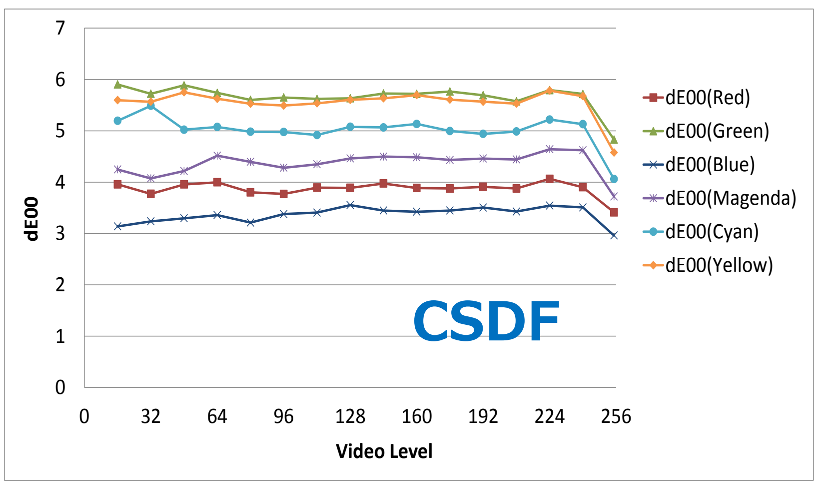
- Images
  - 6 Myocardial perfusion phantom images
  - 6 Cerebral blood flow phantom images
- Color scales
  - 8 color scales (GE Color, GE Rainbow, Toshiba Rainbow5500, Toshiba Rainbow White, Toshiba HotMetal, Siemens ECAT Rainbow, Siemens HotBody and Siemens Spectrum)

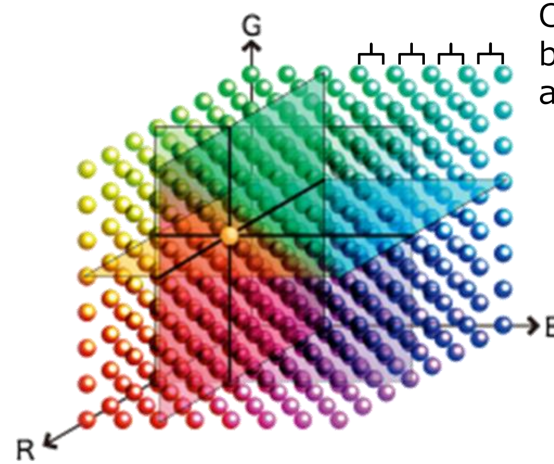
Experimental Condition

- The results of calculation of dE00 for each gamma setting









Calculate dE00 between adjacent colors

Experimental Condition

- LCD display
  - EIZO ColorEdge CG318-4K
  - Display gamma 2.2, GSDF and CSDF

- Observers
  - 2 Radiologists
  - 3 Radiology technologists

- Images
  - 6 Myocardial perfusion phantom images
  - 6 Cerebral blood flow phantom images

- Color scales
  - 8 color scales (GE Color, GE Rainbow, Toshiba Rainbow5500, Toshiba Rainbow White, Toshiba HotMetal, Siemens ECAT Rainbow, Siemens HotBody and Siemens Spectrum)

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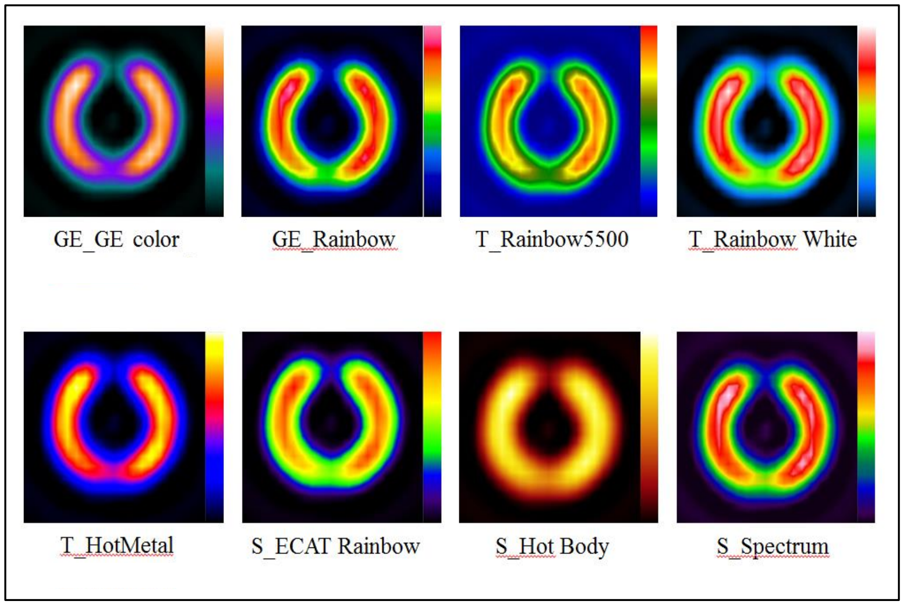
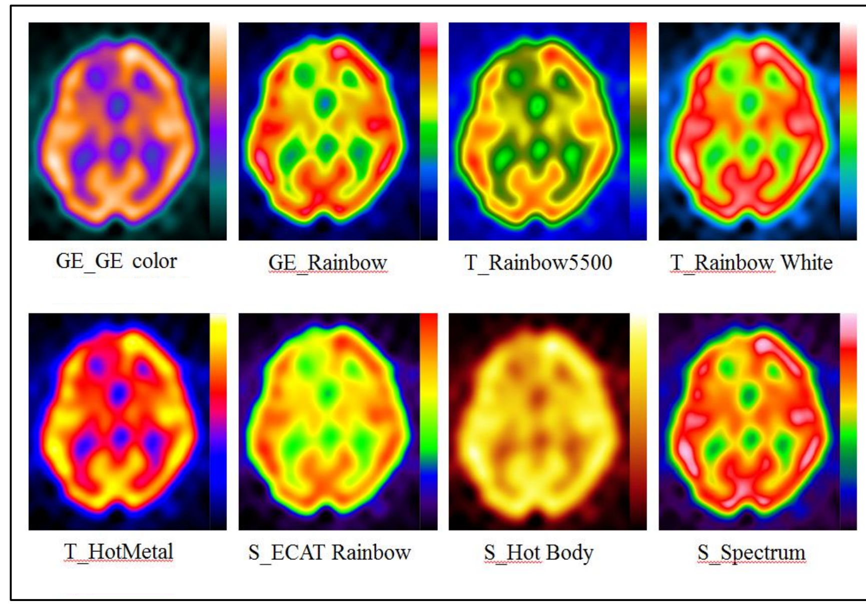
Experimental Condition

- The example images in myocardial perfusion phantom and cerebral blood flow phantom with 8 different color scales



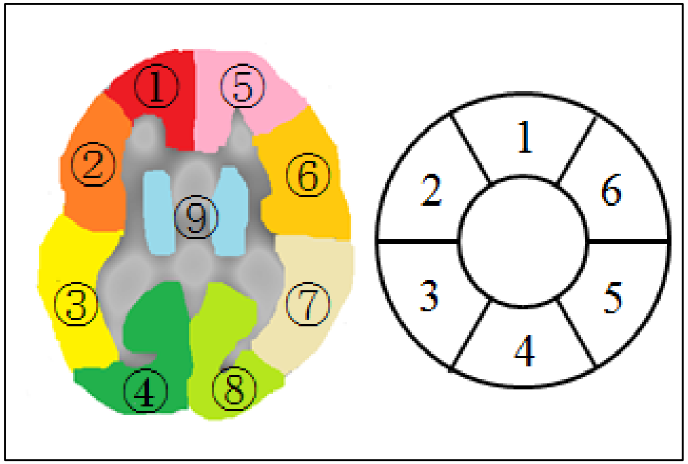
Myocardial perfusion phantom images



Cerebral blood flow phantom images

6 images x **3** display gammas x **8** color scales = **144** patterns

Experimental Method

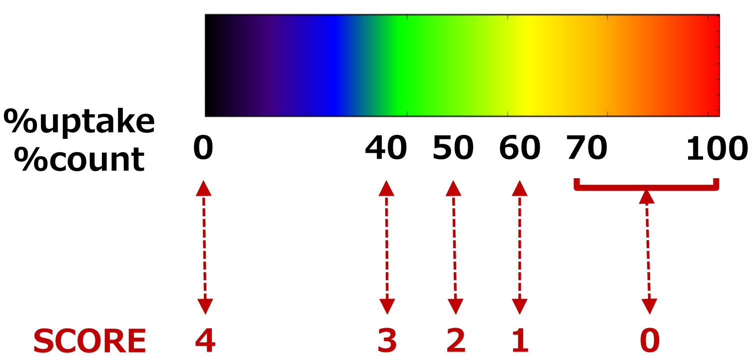


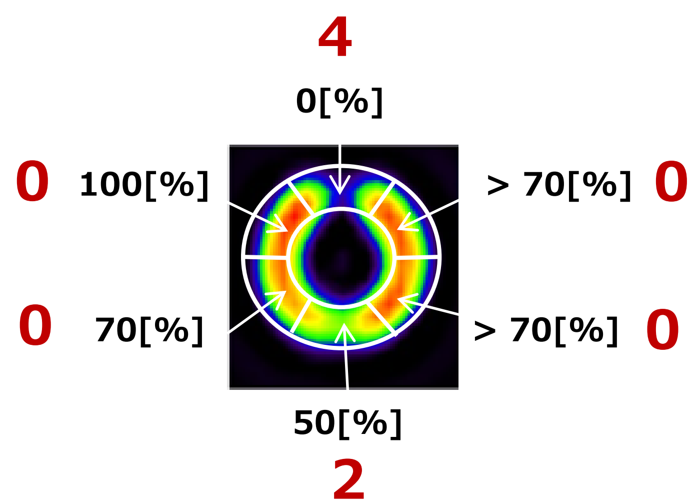
Cerebral blood flow images

Myocardial perfusion images

Segment (Brain)
1 Right frontal lobe
2 Right anterior temporal lobe
3 Right posterior temporal lobe
4 Right occipital lobe
5 Left frontal lobe
6 Left anterior temporal lobe
7 Left posterior temporal lobe
8 Left occipital lobe
9 Thalamus

Segment (Myocardium)
1 Anterior wall
2 Anteroseptal wall
3 Inferoseptal wall
4 Inferior wall
5 Inferolateral wall
6 Anterolateral wall

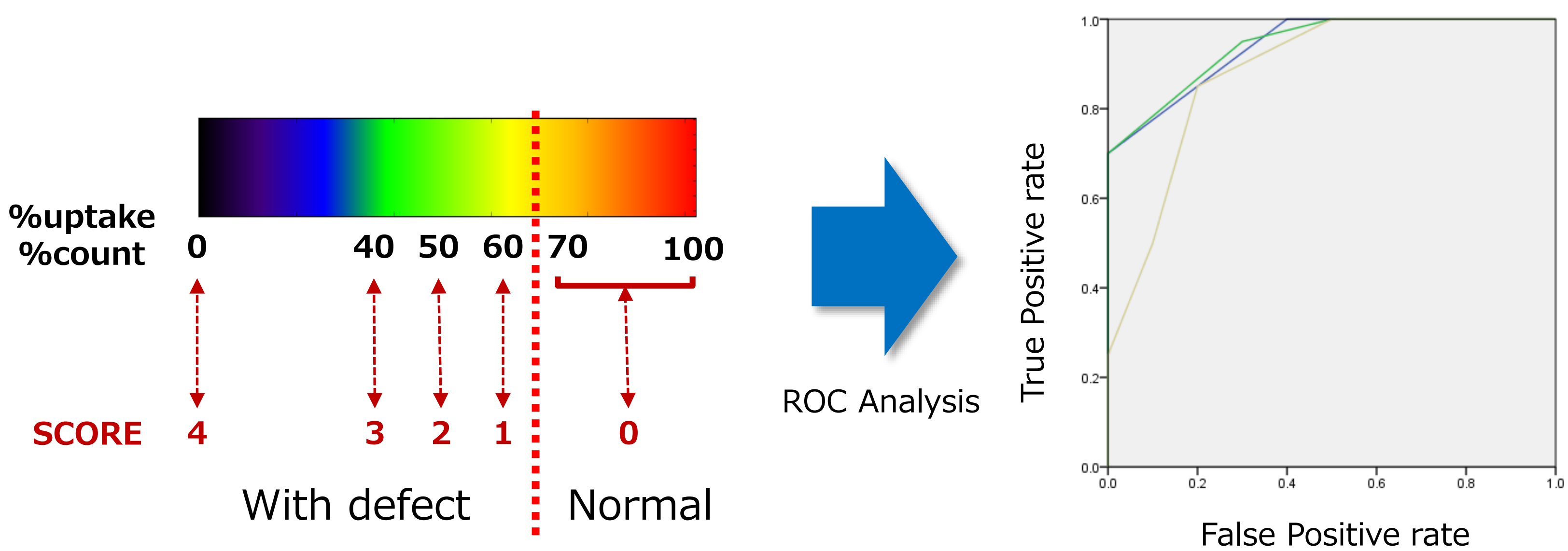




http://www.jsnc.org/p-jsnc-seminar/001/2010/0719-3

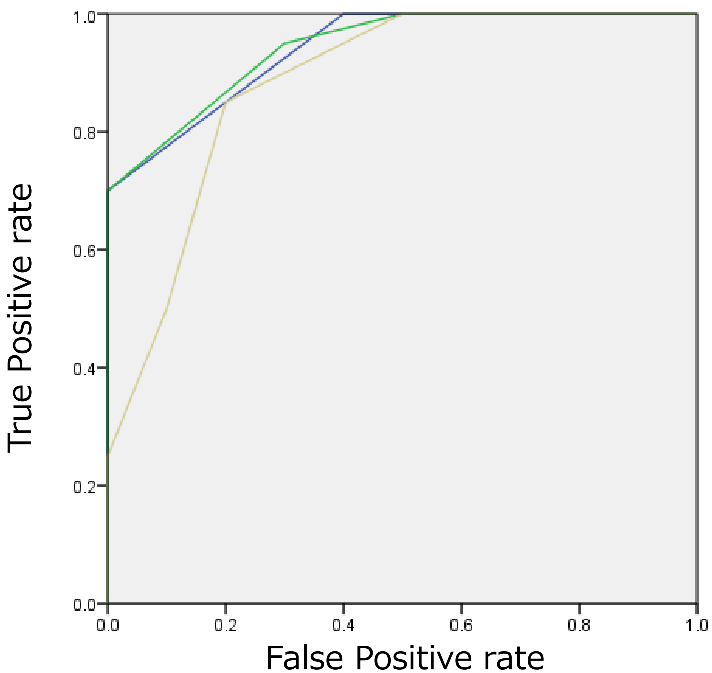
Experimental Method

- Evaluation method
  - ROC analysis by Statistical Package for Social Science (SPSS) ver.23



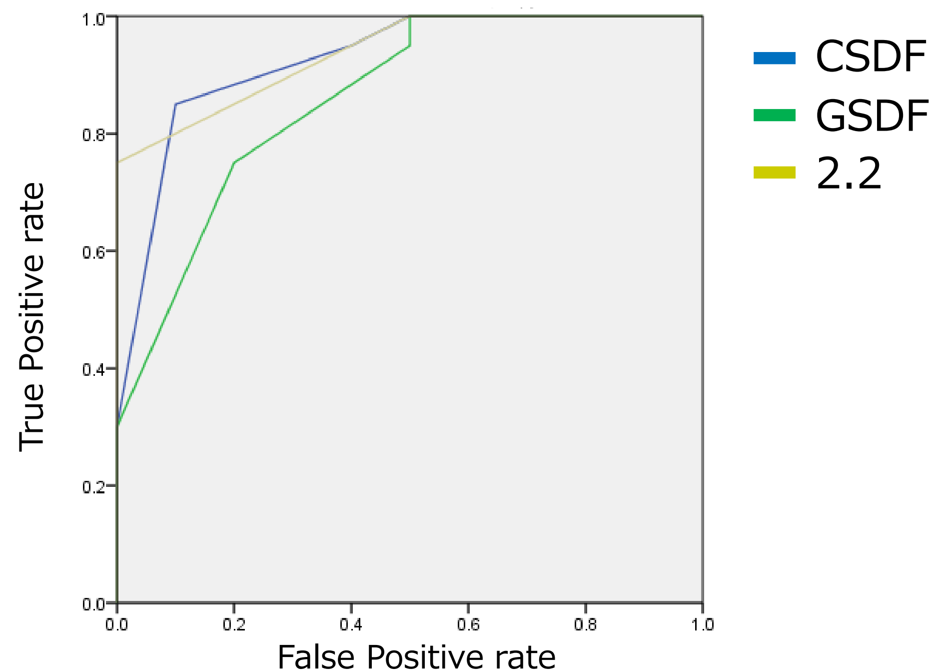
Experimental Results

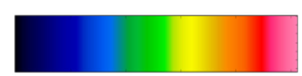
- Cerebral blood flow phantom images (1/2)



GE Color 

	CSDF	GSDF	2.2
Az	0.940	**0.942**	0.883



GE Rainbow 

	CSDF	GSDF	2.2
Az	0.925	0.860	**0.938**

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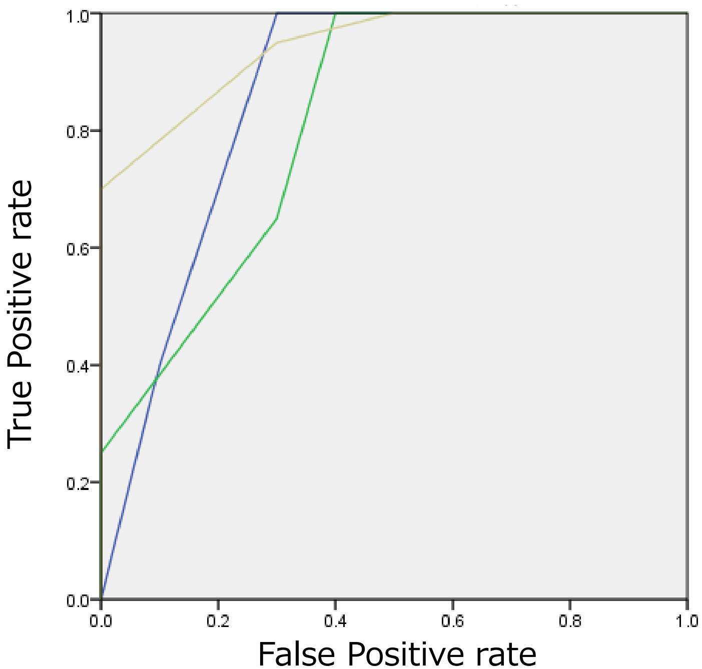
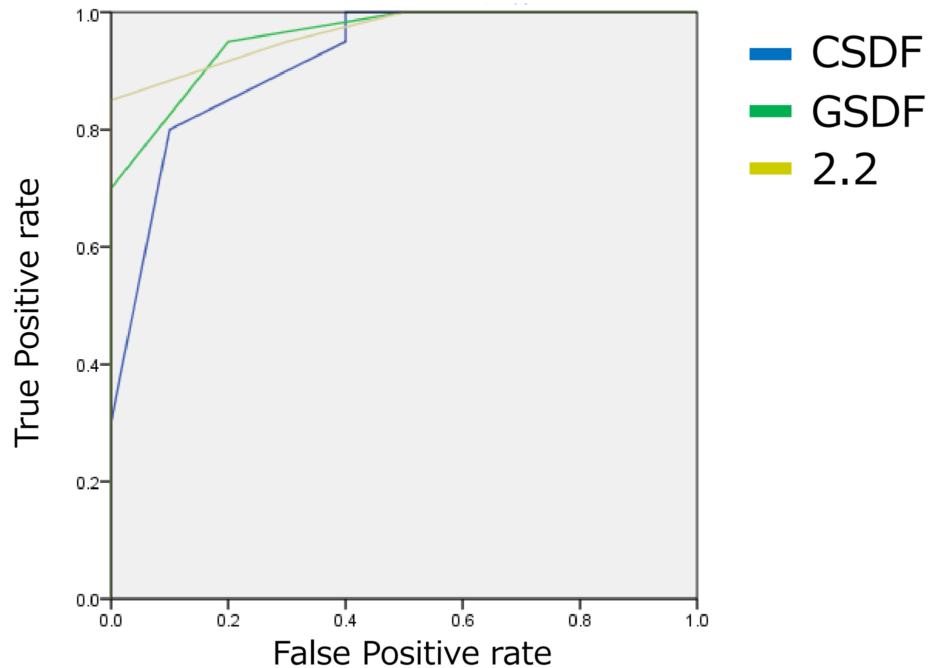
Experimental Results

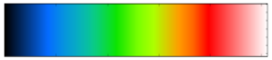
- Cerebral blood flow phantom images (2/2)





Toshiba Rainbow 5500 

	CSDF	GSDF	2.2
Az	0.860	0.818	**0.942**

Toshiba Rainbow White 

	CSDF	GSDF	2.2
Az	0.918	0.957	**0.965**

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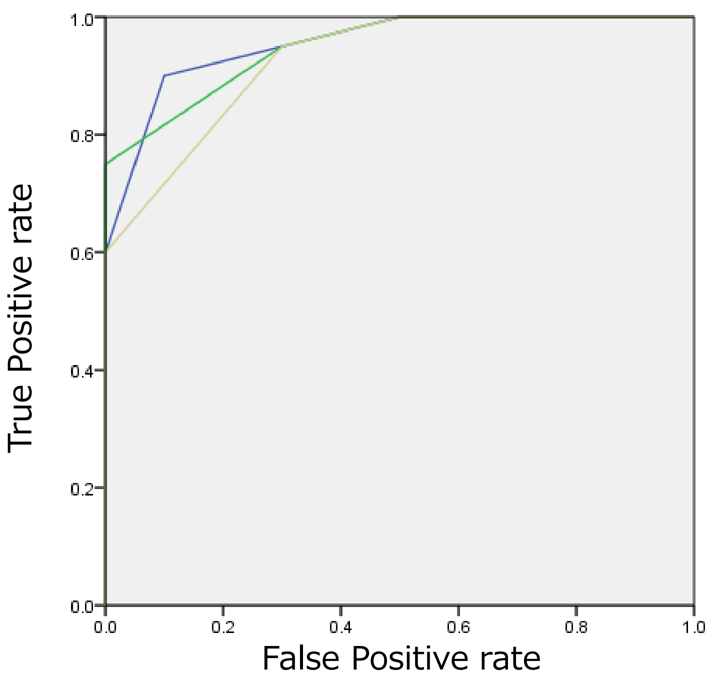
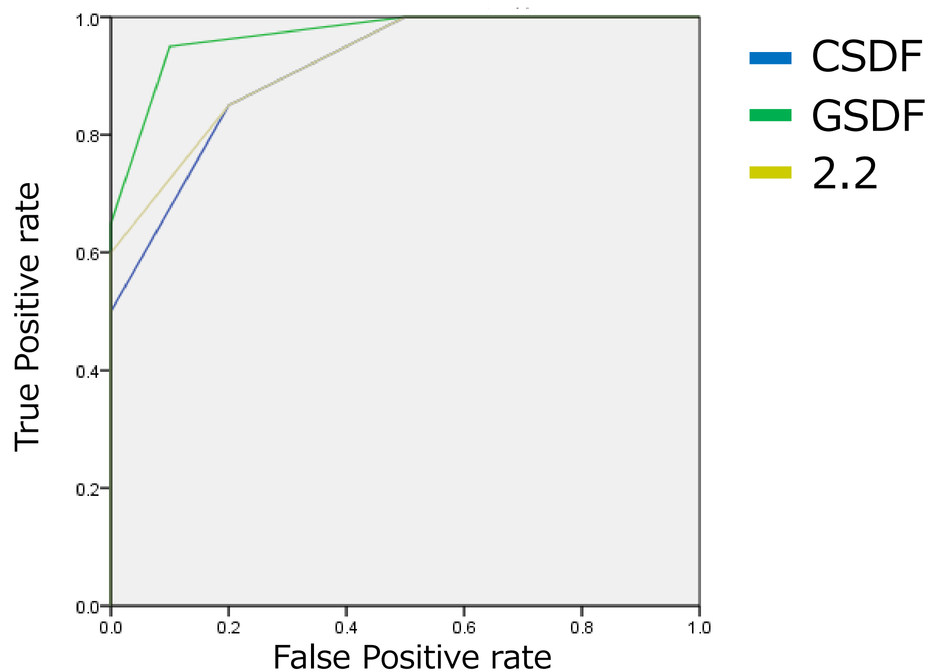
Experimental Results

- Myocardial perfusion phantom images (1/2)



Toshiba HotMetal

	CSDF	GSDF	2.2
Az	**0.955**	0.950	0.927

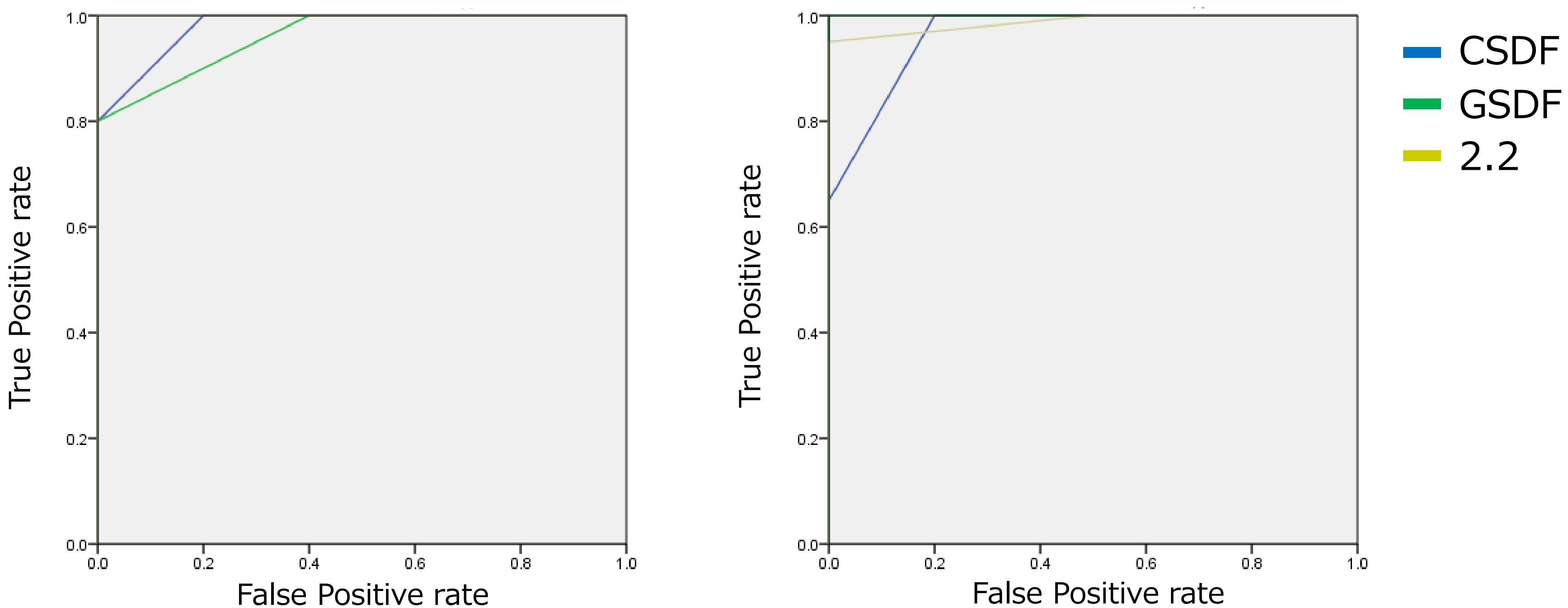


Siemens ECAT Rainbow

	CSDF	GSDF	2.2
Az	0.913	**0.970**	0.923

Experimental Results

- Myocardial perfusion phantom images (2/2)



Siemens Hot Body

	CSDF	GSDF	2.2
Az	0.980	0.960	**1.000**

Siemens Spectrum

	CSDF	GSDF	2.2
Az	0.965	**1.000**	0.987

Conclusions

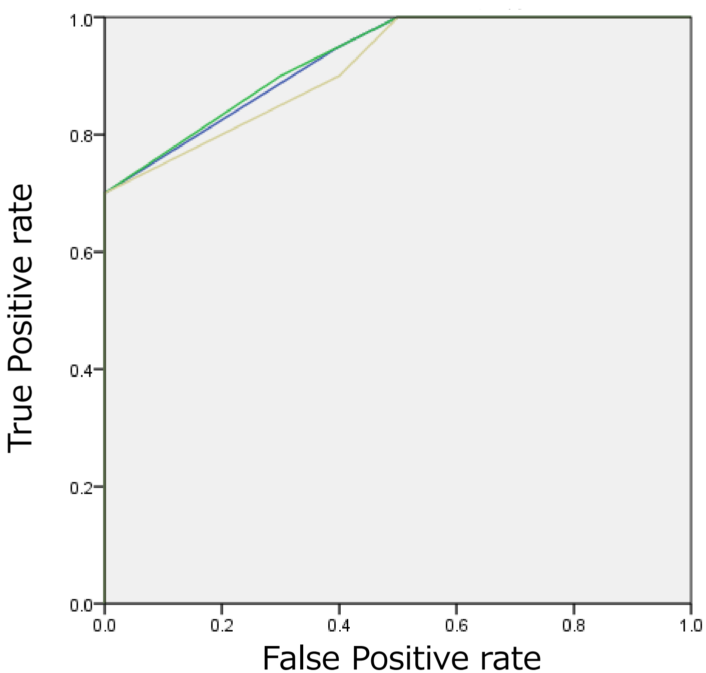
- The ROC analysis revealed that Az values varied according to the combination of display gamma and color scale. Therefore, it is difficult to decide which display gamma is superior for nuclear medicine to others.

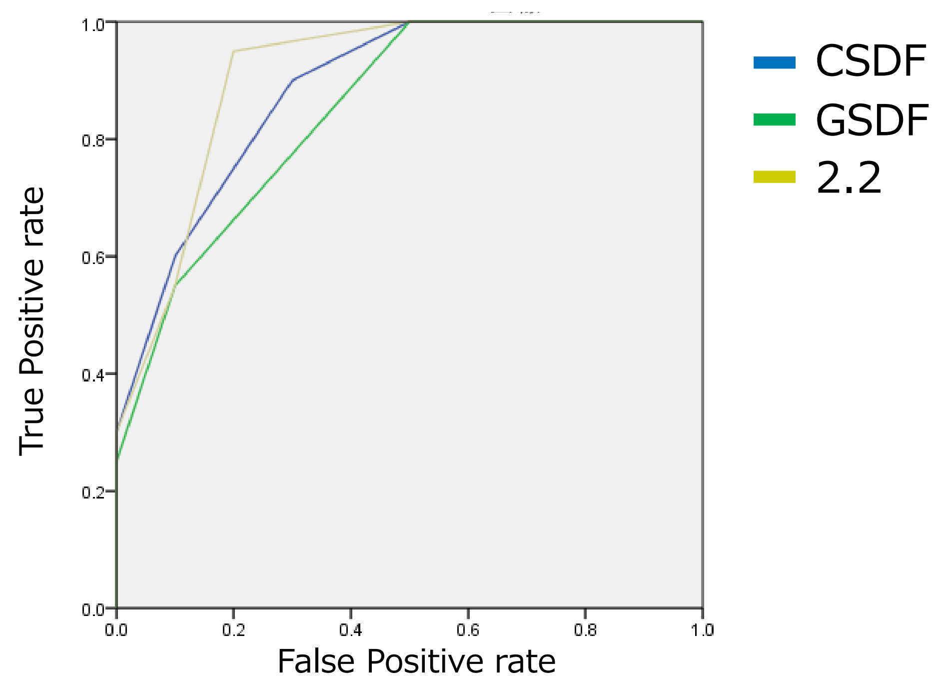
- Considering that commercial LCD displays (gamma 2.2) are mainly used in nuclear medicine, gamma 2.2 is easier to achieve and maintain consistency of image presentation across different displays.

Appendix

Experimental Results

- Cerebral blood flow phantom images (3/4)





Toshiba HotMetal

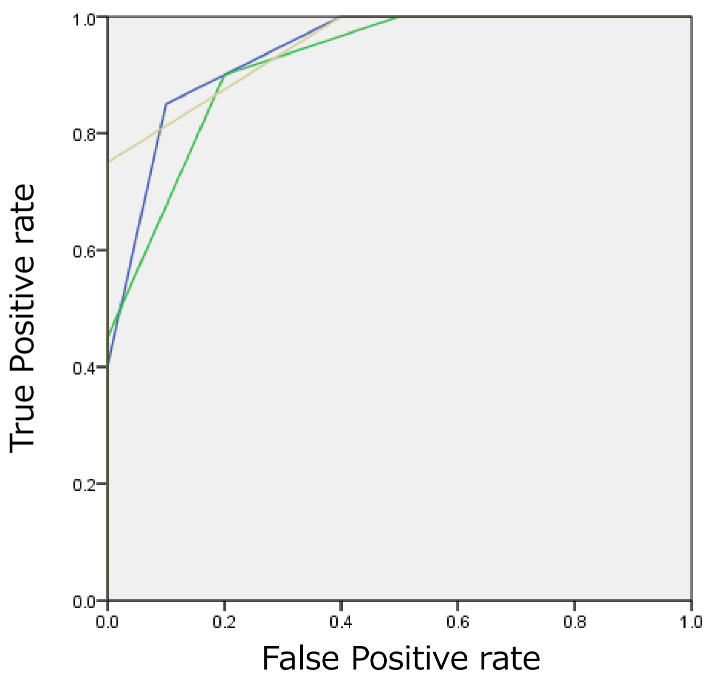
	CSDF	GSDF	2.2
Az	0.928	**0.930**	0.915

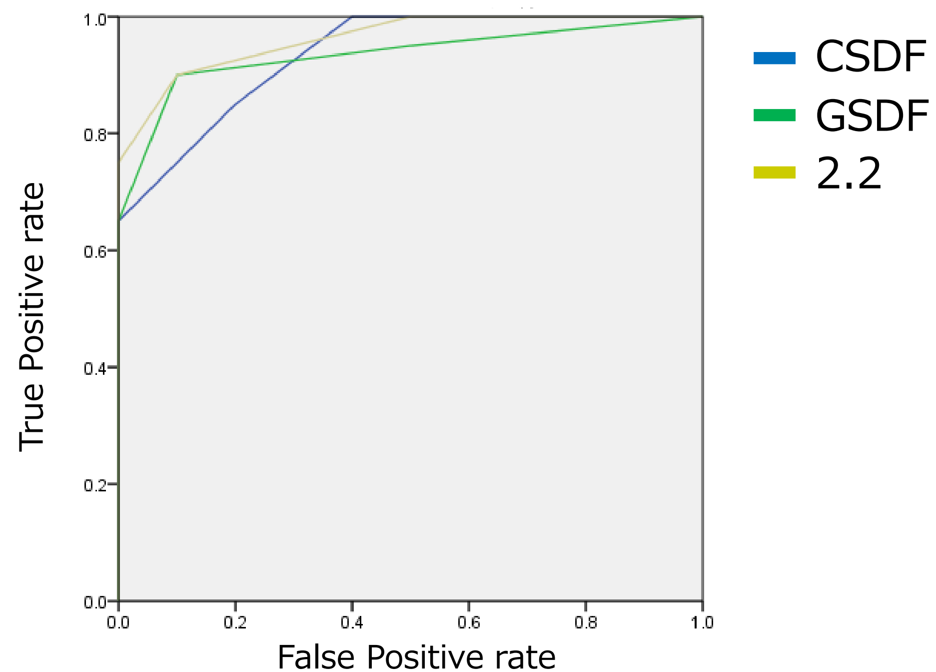
Siemens ECAT Rainbow

	CSDF	GSDF	2.2
Az	0.885	0.850	**0.910**

Experimental Results

- Cerebral blood flow phantom images (4/4)





Siemens Hot Body

	CSDF	GSDF	2.2
Az	0.940	0.920	**0.950**

Siemens Spectrum

	CSDF	GSDF	2.2
Az	0.935	0.935	**0.963**

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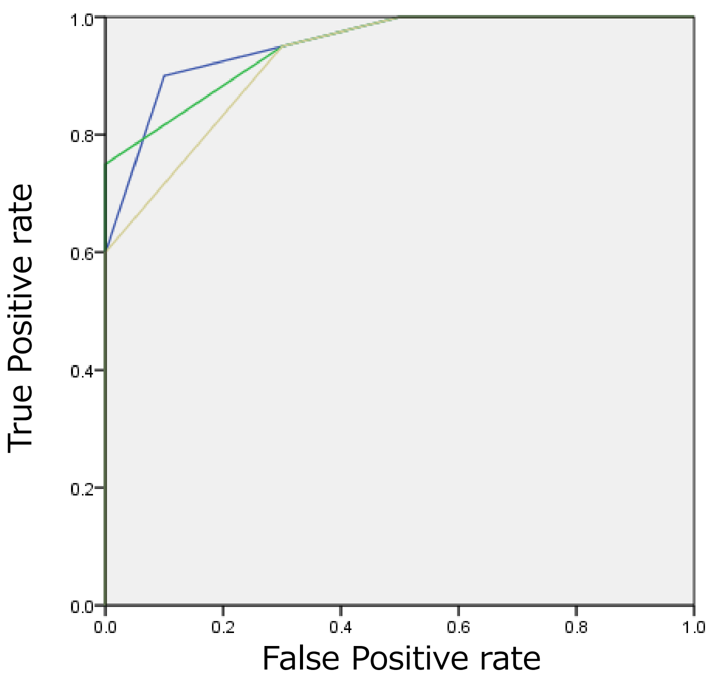
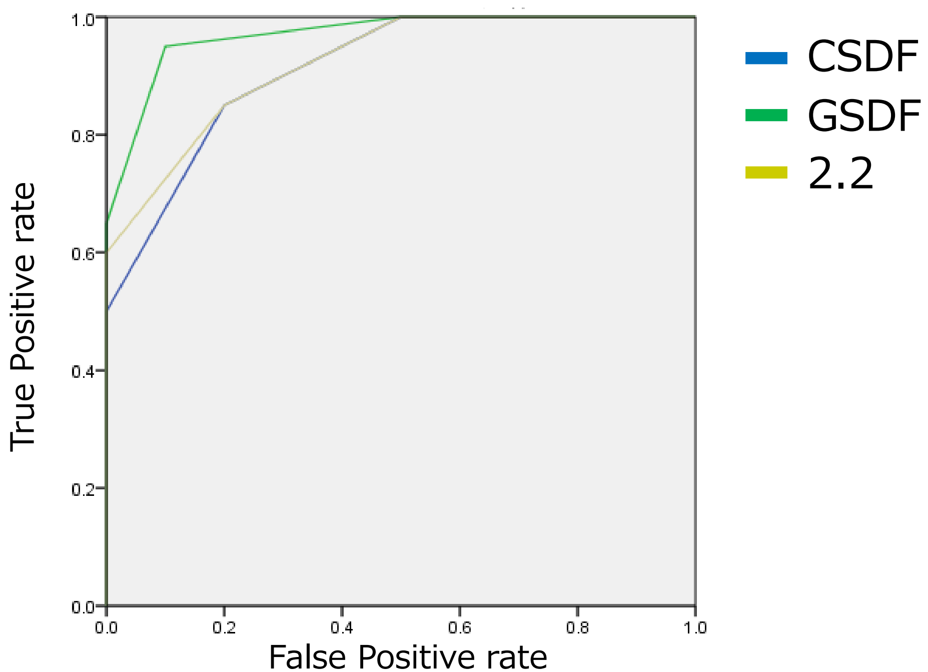
Experimental Results

- Myocardial perfusion phantom images (3/4)



Toshiba HotMetal

	CSDF	GSDF	2.2
Az	**0.955**	0.950	0.927



Siemens ECAT Rainbow

	CSDF	GSDF	2.2
Az	0.913	**0.970**	0.923

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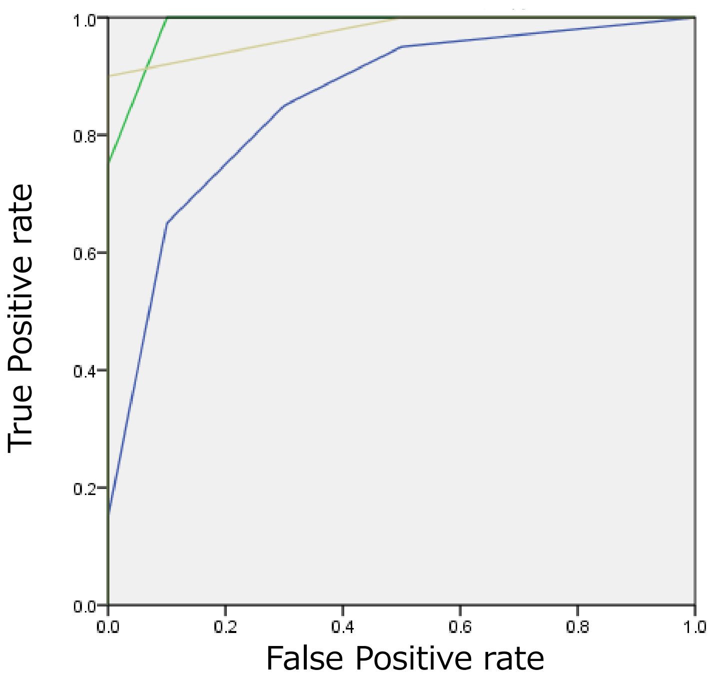
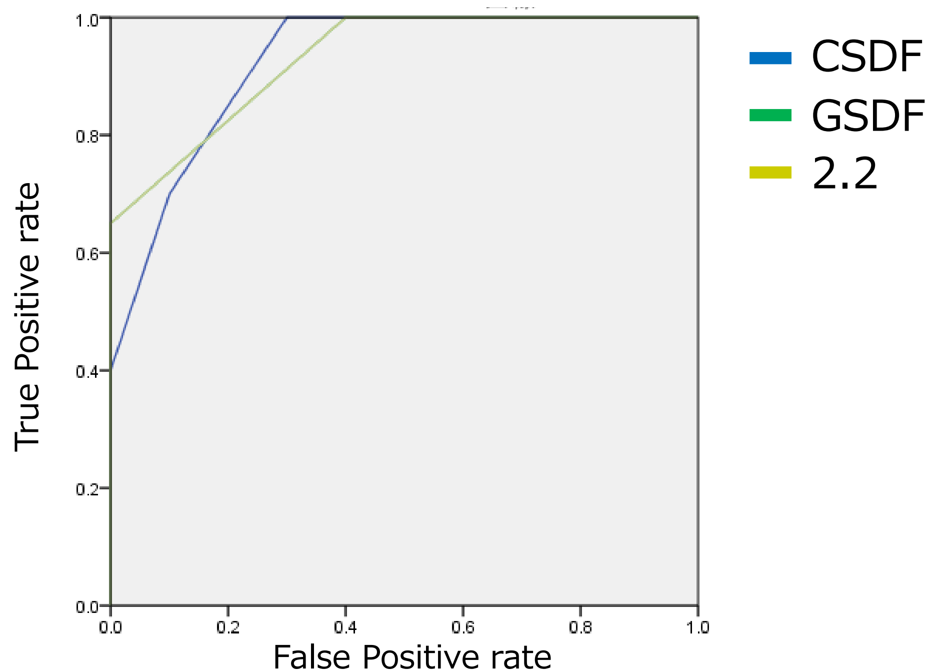
Experimental Results

- Myocardial perfusion phantom images (1/2)



GE Color

	CSDF	GSDF	2.2
Az	0.858	**0.988**	0.975

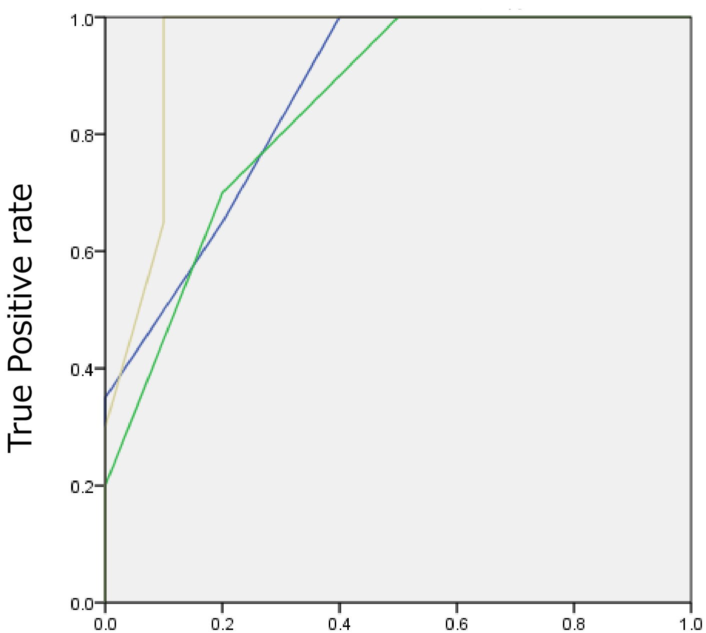


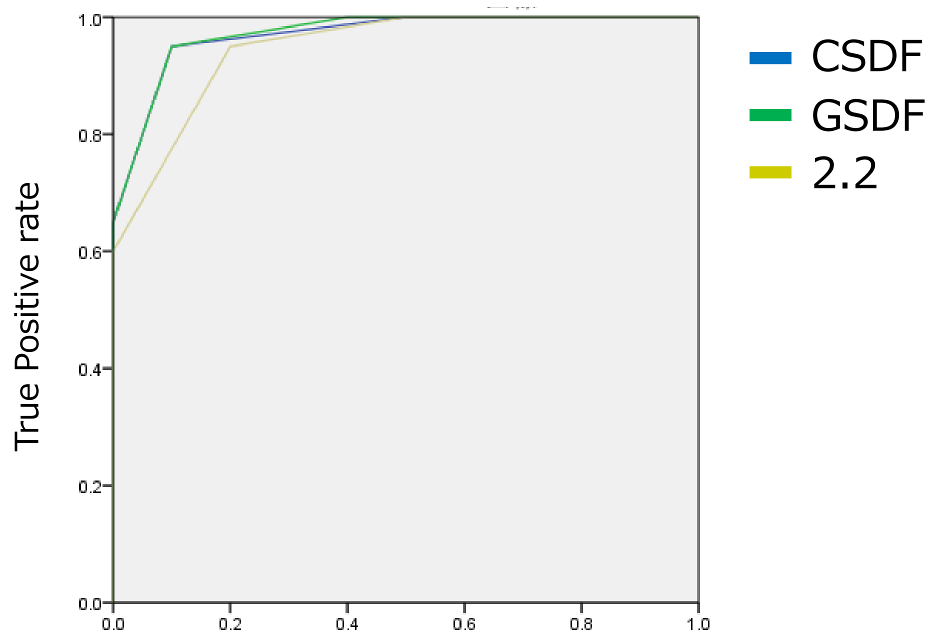
GE Rainbow

	CSDF	GSDF	2.2
Az	0.925	**0.930**	**0.930**

Experimental Results

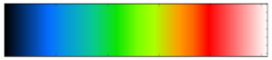
- Myocardial perfusion phantom images (2/2)





Toshiba Rainbow 5500 

	CSDF	GSDF	2.2
Az	0.865	0.845	**0.948**

Toshiba Rainbow White 

	CSDF	GSDF	2.2
Az	0.970	**0.972**	0.947

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ICC Working Group Meeting (MIWG), Tokyo, JAPAN Apr. 19~20

IPS

Electro-Optical Requirements for Medical Display

Wonseon, Song

WRGB OLED

Apr. 20. 2017

LG Display

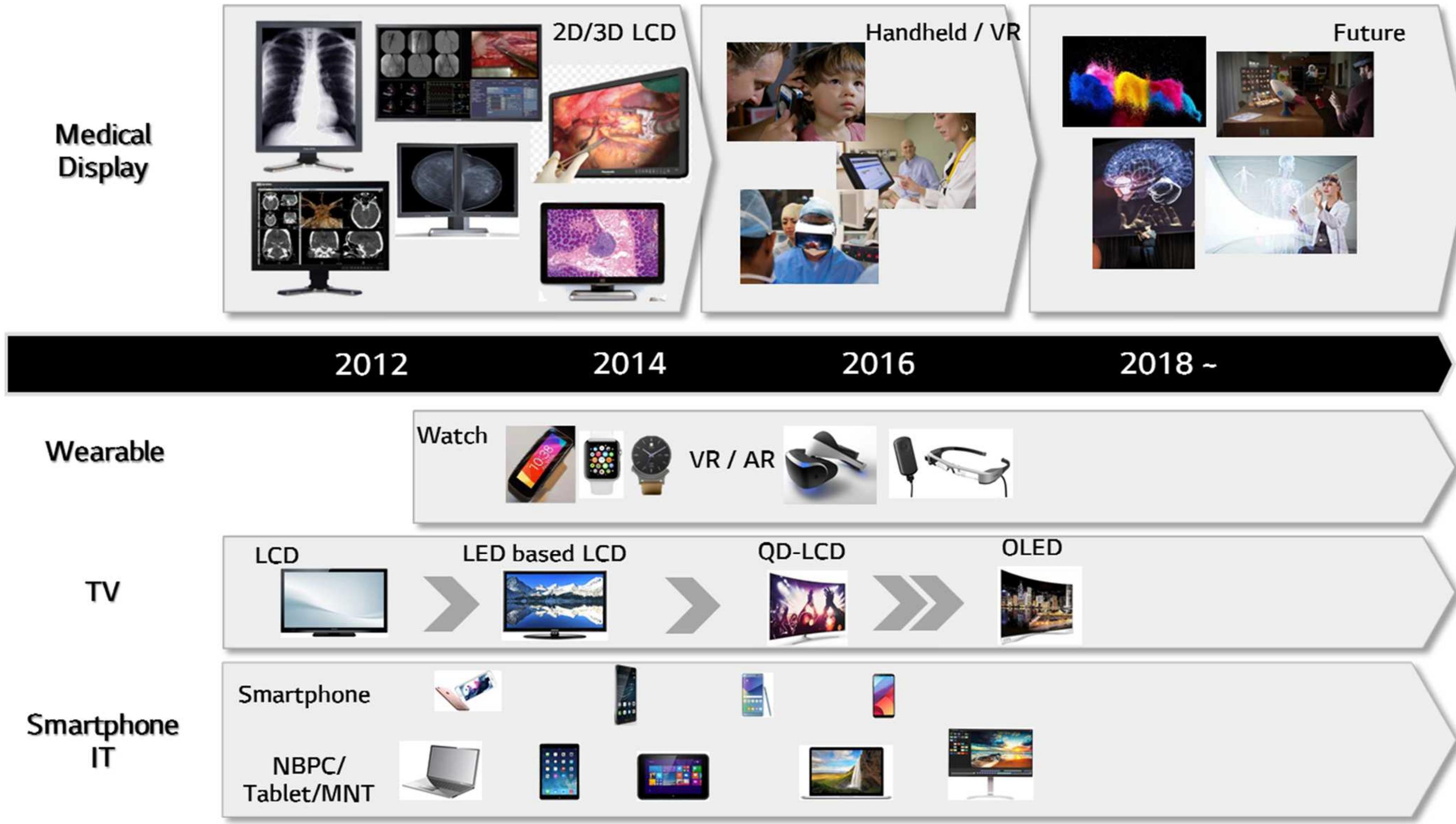
Contents

1. Medical Display Trend
2. Progress of Display Technology
3. Image Quality Circle
4. Requirements of Medical Display
5. Future works & discussions

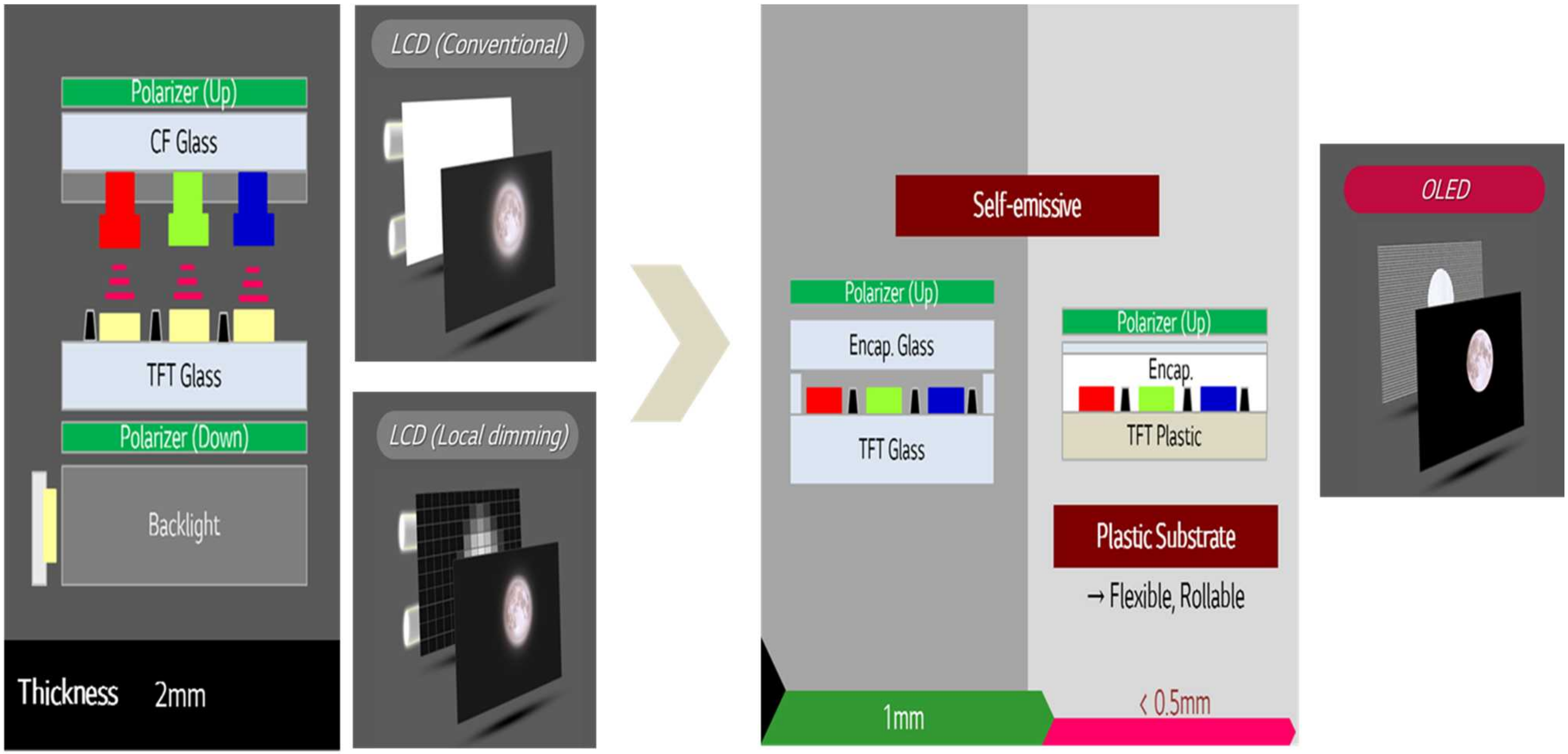
LG Display

1. Medical Display Trends

Display technology has found its way into various consumer electronics, and now medical industry needs to innovate in medical display.



- Displays are evolving from PDPs to LCDs and now to OLEDs.
- The goal is to bring the color to the nearest human eye and finally display it on the screen.

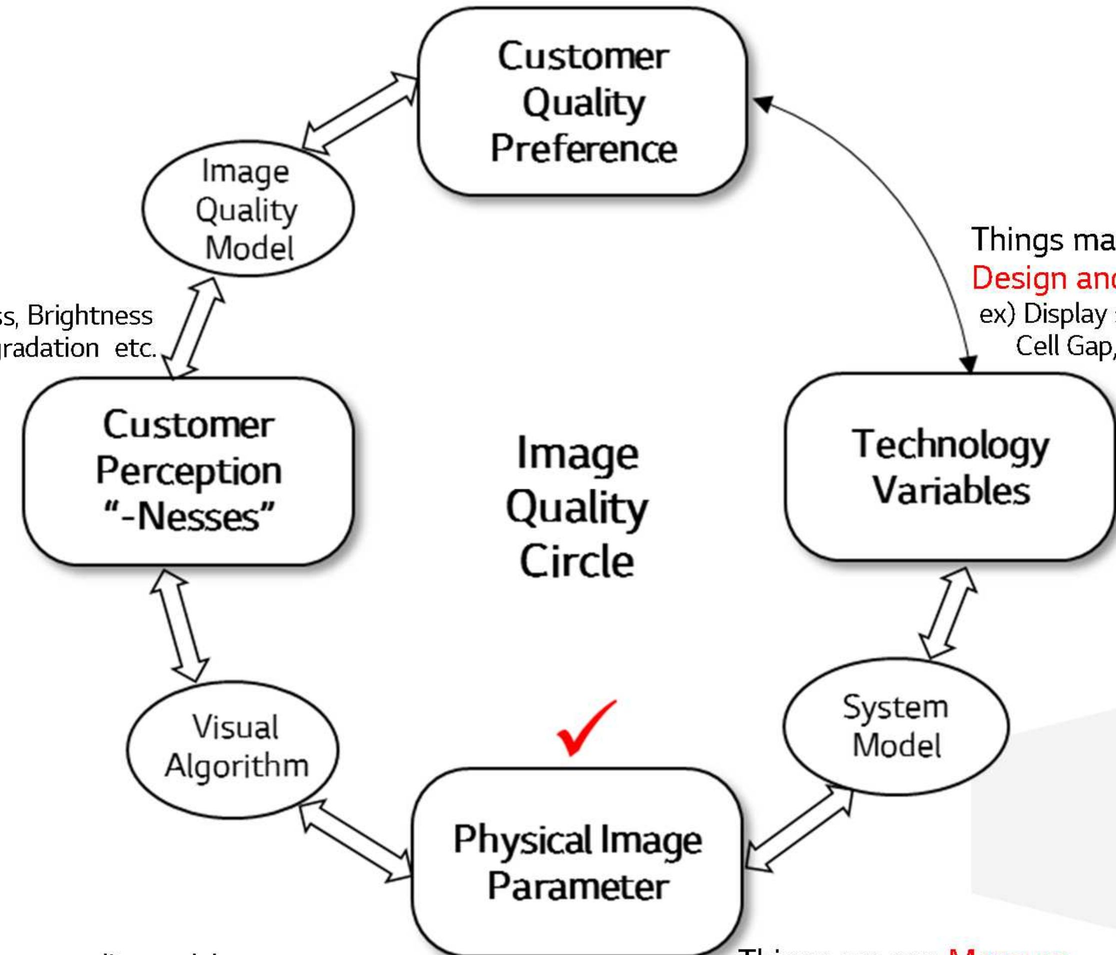


LCD OLED

※ http://blog.lgdisplay.com, LG Display blog

LG Display

- To evaluate physical performance of medical display, manufactures should measure key physical image parameters.



Things people can See
ex) Sharpness, colourfulness, Brightness
Naturalness, Contrast, gradation etc.

Things manufacturer can Design and Control
ex) Display size, Sub-pixel size,
Cell Gap, C/F etc.

Things we can Measure
ex) Luminance, Chromaticity(x, y), Gamma,
Crosstalk, Response time etc.

Key parameters

- Luminance
- Bit-depth
- Viewing Angle
- Ambient Light
- Pure Black
- Peak luminance
- Contrast
- Color
- HDR

※ Engeldrum,P.G. (1999), Image quality models: Where are we?, PICS conference, IS&T, pp 251

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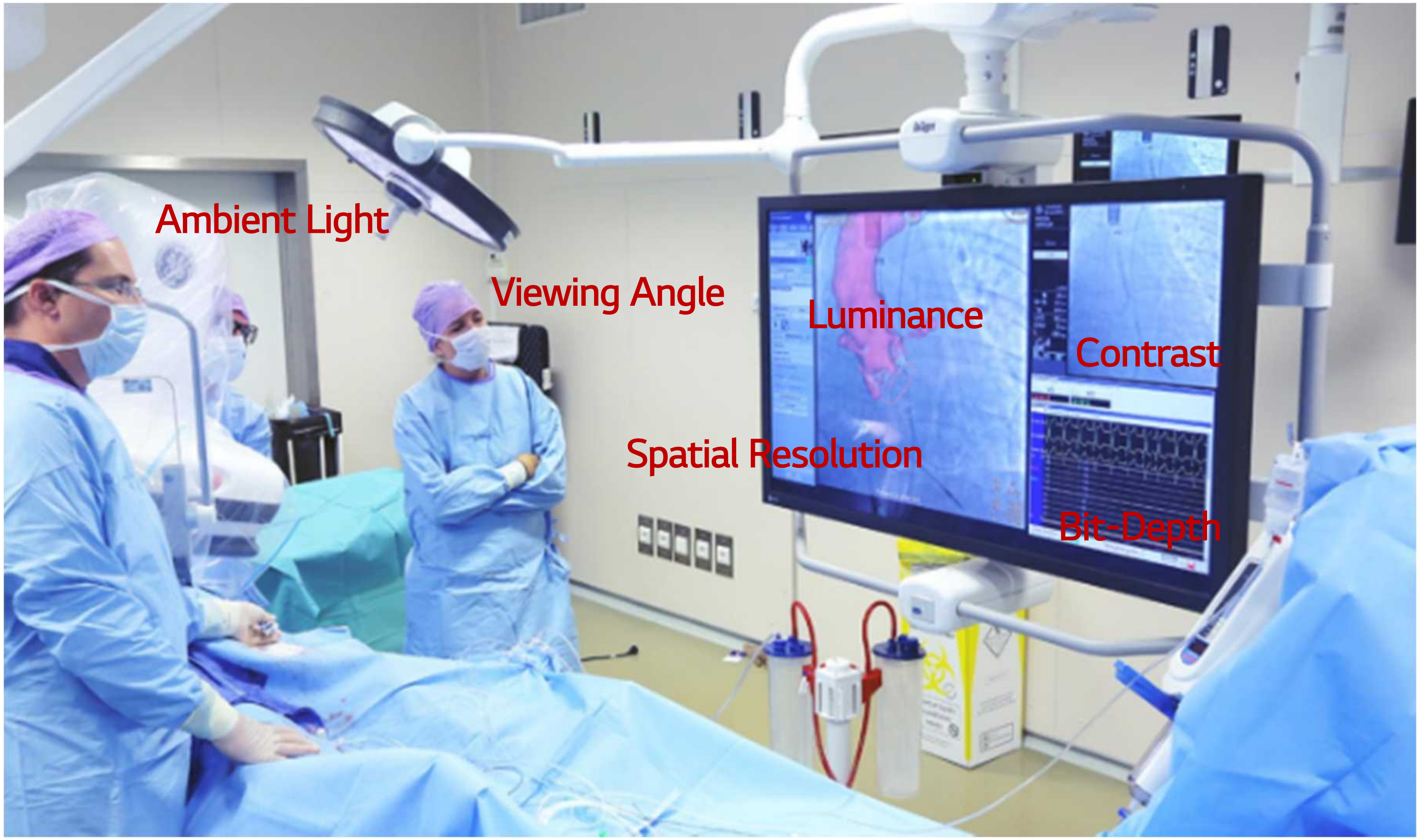
4. Requirements for Medical Display

- Medical Displays require more accurate Electro-Optical Properties



4. Requirements for Medical Display

- No light leakage and pure black performance are important attributes to represent wide dynamic range of contents on medical display.

Display A

- Black Luminance ~ 0.0003 cd/m²
- No Halo

Display B

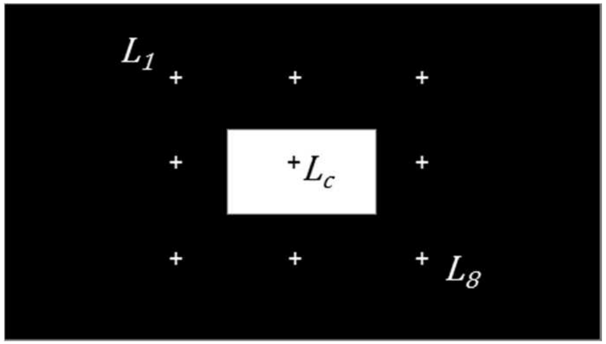
- Black Luminance ~ 0.2 cd/m²
- Halo Artifact

- Local contrast indicates how well a display can express images when bright and dark regions are displayed simultaneously.

Both dark and bright regions appear simultaneously

$$Local\ contrast = \frac{8L_c}{\sum L_i}$$

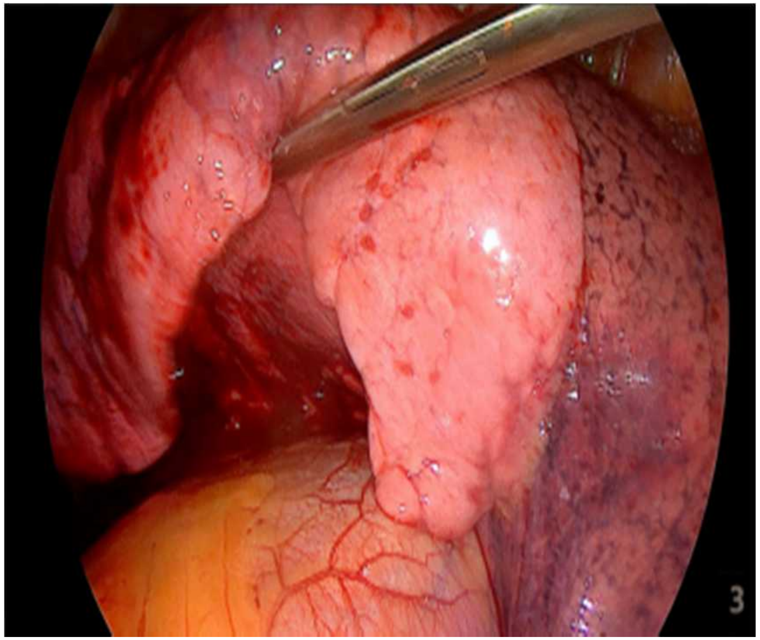
L_c : luminance of center
L_i : the black surround at the eight locations



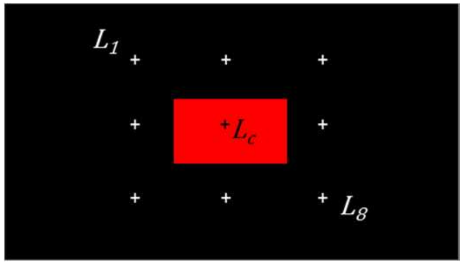
	Display A	Display C
Local contrast	1088K:1	19.5K:1

4. Requirements of Medical Display

- Higher color contrast makes more vivid and vibrant colors even though displays have similar color coordinate values.



Example for Color Contrast



$$\text{Color contrast} = \frac{8L_c}{\sum L_i}$$

L_c : *luminance of center*

L_i : *the black surround at the eight locations*

	Display A	Display C
Red	120,000:1	4,700:1
Green	400,000:1	17,000:1
Blue	64,000:1	2,300:1

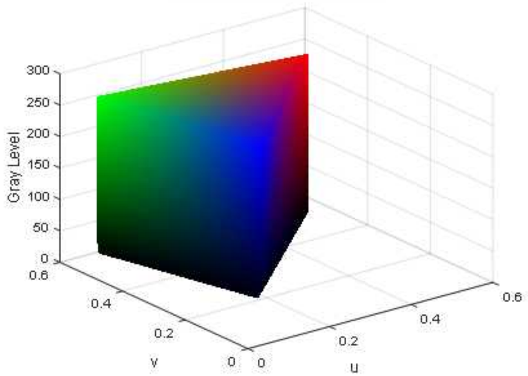
※ The Picture Quality of OLED TV, OLEDs World Summit, 2016, JJ Yoo

4. Requirements of Medical Display

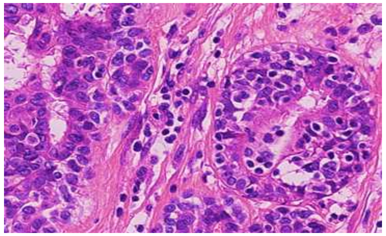
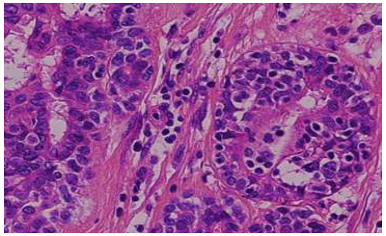
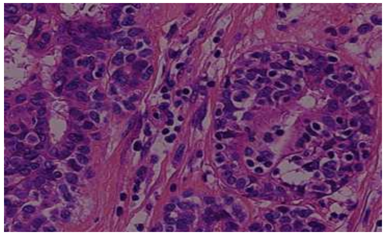
(5) CG Consistency

- Constant color gamut at all gray level is also important performance for Medical display.
  → 'Display A' looks brighter, sharper and more visually pleasing at all gray level.

Display A

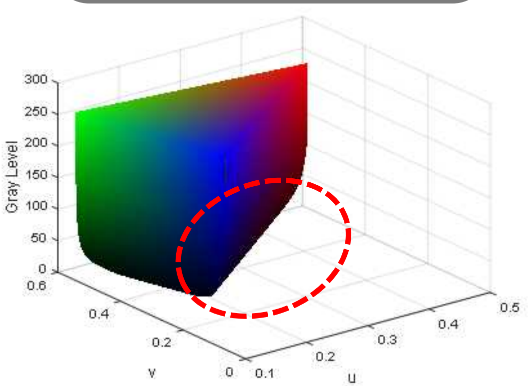


Brightness level 100% → Brightness level 50% → ✓Brightness level 20%

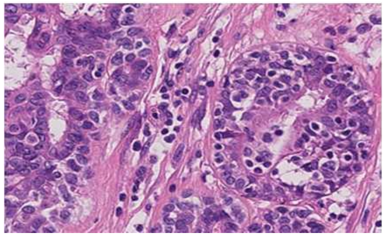
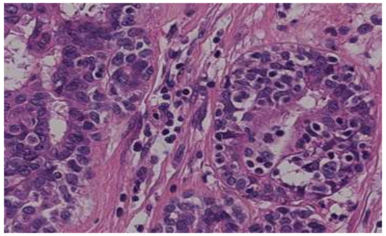
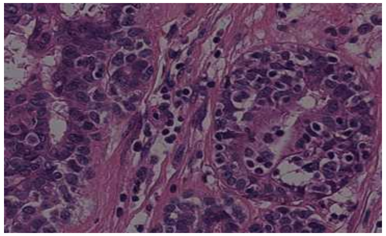




Color Gamut 100 % → Color Gamut 100% → Color Gamut 83%

Display C



Brightness level 100% → Brightness level 50% → ✓Brightness level 20%

Color Gamut 100 % → Color Gamut 55% → Color Gamut 14%

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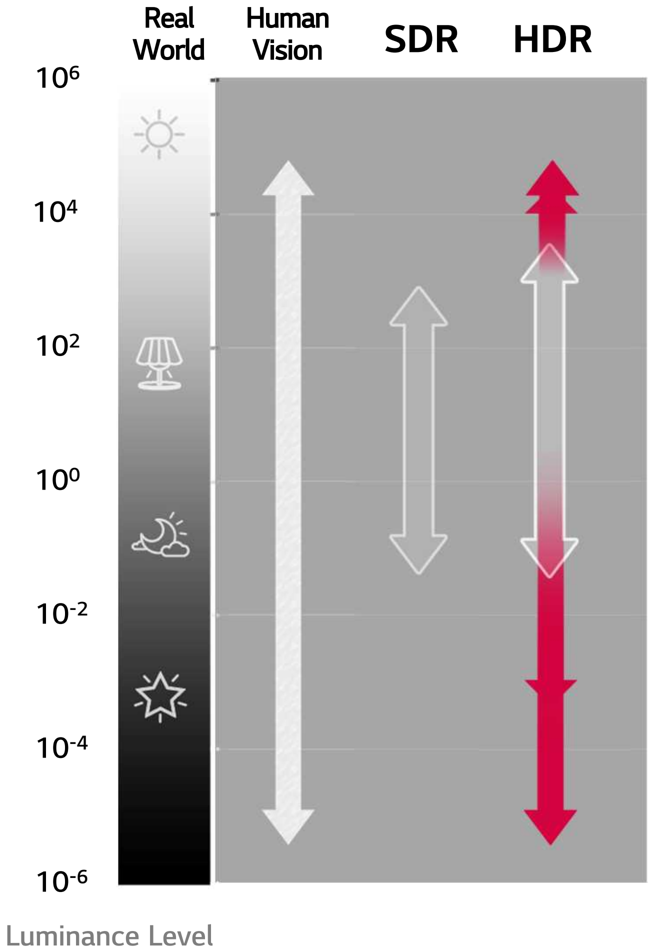
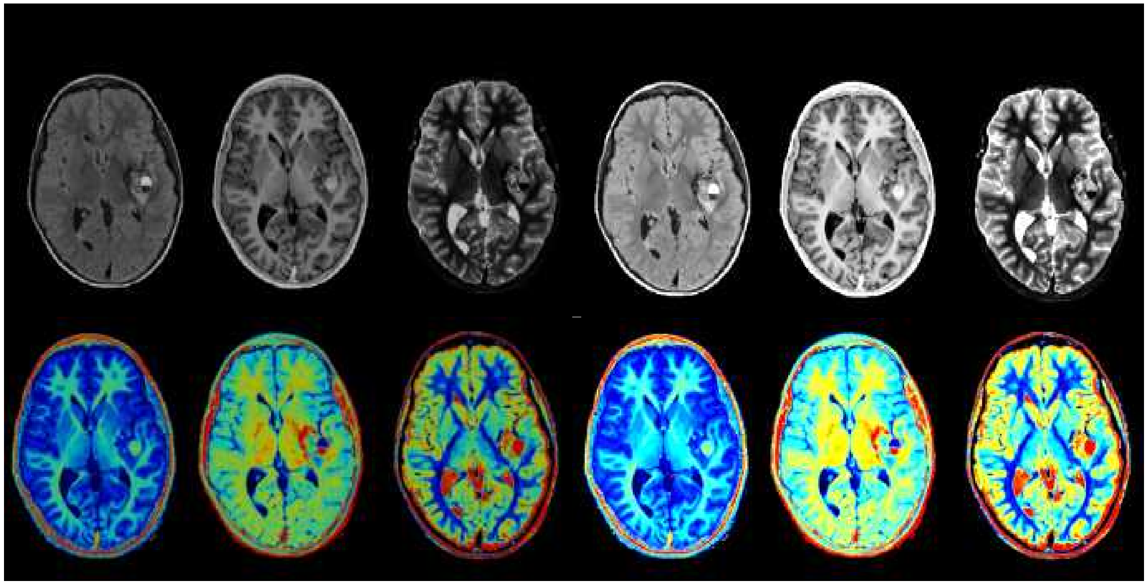
4. Requirements of Medical Display

- HDR performance is also becoming increasingly important in medical displays



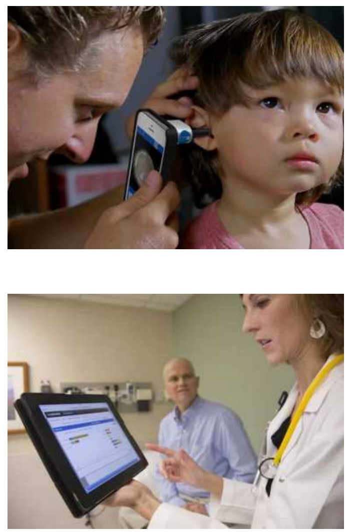
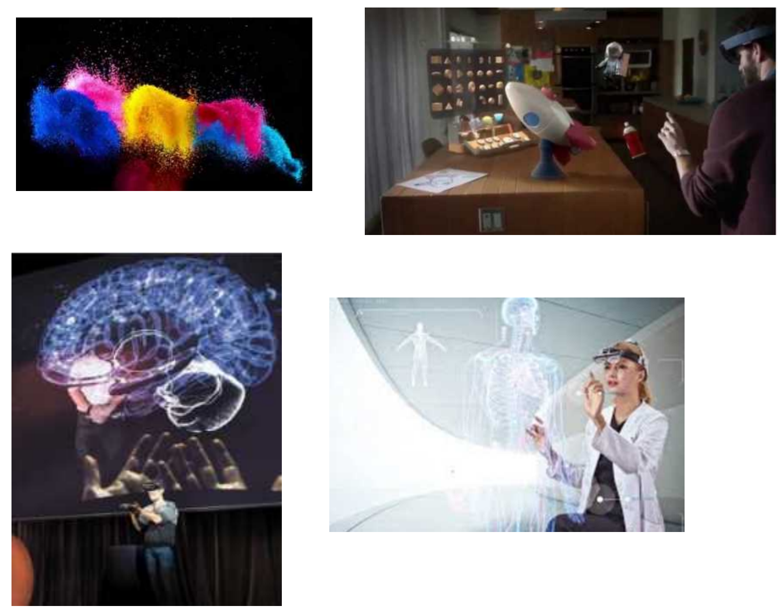


Standard Dynamic Range

High Dynamic Range

5. Future works & discussions

- We will prepare for new physical measurement and visual assessment of emerging applications for medical display.

LCD		OLED / pOLED
		
▪ Display for Medical Application	▪ Medical IT Devices ▪ 3D, VR, AR etc.	▪ Fast Response, Wide Color Gamut ▪ Customized Medical IT Devices