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Using DeEP* Device Enhancement Processing Technology for ERCP

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1. Introduction

Endoscopic retrograde cholangiopancreatography (ERCP) is a procedure that injects contrast medium via a contrast catheter into the bile and pancreatic ducts that exit into the duodenum at the papilla of Vater. ERCP is commonly used to diagnose bile duct cancer and pancreatic cancer, treat obstructive jaundice, and remove common bile duct (CBD) stones.

Many types of devices are used in ERCP procedures, including ERCP cannulas used to introduce contrast medium for contrast radiography of the bile and pancreatic ducts, guidewires to assist with device insertion, dilating balloons to expand narrow ducts, baskets to crush CBD stones, stone retrieval balloons and baskets to remove crushed stones, and plastic or metal stents for obstructive jaundice. Thus, ERCP procedures are essential for the diagnosis and treatment of many biliopancreatic disorders. ERCP procedures are for the most part performed under fluoroscopic guidance, hence accurate diagnosis and treatment would be difficult without high quality fluoroscopic images of ERCP devices, even if improvements are made to these devices. For this reason and due to increasing controls on radiation exposure in recent years, when our Department of Endoscopy was relocated and expanded with the construction of a new outpatient building in 2020, a SONIALVISION G4 LX edition (SONIALVISION G4 LX) R/F system that offers both low dose levels and high image quality was procured for the new fluoroscopy room.

2. Department of Endoscopy, The Jikei University School of Medicine

The Department of Endoscopy in our hospital started in 1986 as the second established Department of Endoscopy in university hospital in Japan. Today, the Department of Endoscopy provides clinical education under the supervision of Professor Kazuki Sumiyama. The newly constructed outpatient building was furnished with 10 private endoscopy rooms, which included one fluoroscopy room. All endoscopy rooms are negative pressure rooms (two with HEPA filtration), and a recovery room with 18 beds in total is centrally managed and separated into individual booths **(Fig. 1)**.

The SONIALVISION G4 LX was selected for the new fluoroscopy room because of the size of the room and the compactness of the control system **(Fig. 2)**.

In 2019, the SONIALVISION G4 LX was used to perform 1,193 biliopancreatic procedures and continues to perform reliably to this day. ERCP with

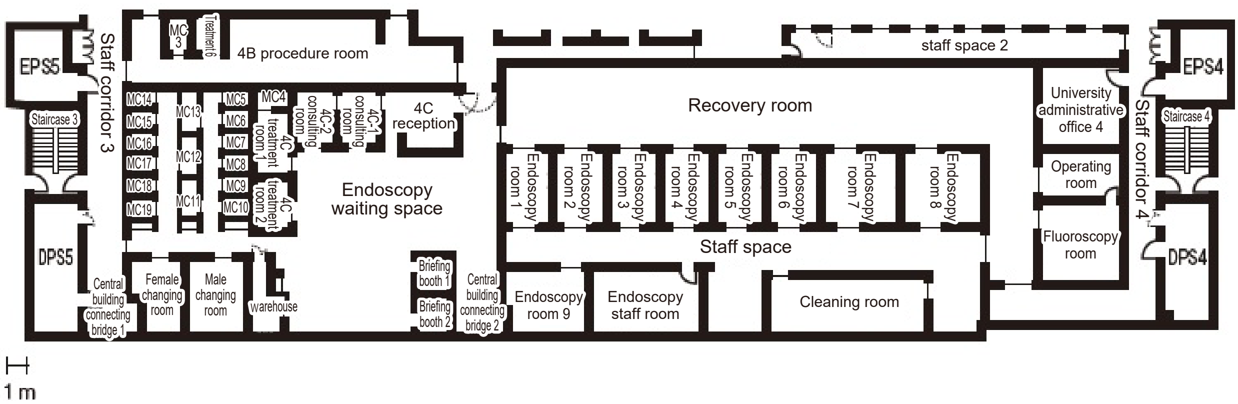


Fig.1 Department of Endoscopy Floor Plan

fluoroscopic imaging accounted for 504 of these 1,193 procedures.

3. Device Enhancement Processing (DeEP)

Our SONIALVISION G4 LX multi-purpose R/F system is equipped with the SCORE PRO Advance fluoroscopic image processing engine for low dose levels and image quality suitable for many different examinations. SCORE PRO Advance is a fluoroscopic image processing technology originally developed by Shimadzu for angiography systems that offers motion tracking-based noise reduction **(Fig. 3)** and object extraction-based edge enhancement that selectively enhances object edges based on their geometric structure **(Fig. 4)**. These features improve noise reduction and the visibility of detailed structures over previous image processing without lags in displaying images and with minimal lag images from inter-frame processing. With these image quality improvements, SCORE PRO Advance produces the same image quality with just 40 % of previous X-ray dose levels. The significant lag reduction provided by SCORE PRO Advance also minimizes loss of visibility at low pulse rates, allowing pulse rates to be reduced for even lower dose levels depending on the examination and type of procedure. The selective enhancement abilities of the object extraction-based edge enhancement feature of SCORE PRO Advance are further strengthened by an additional feature called device enhancement processing (DeEP), which improves the visibility of different types of devices at the same fluoroscopic X-ray dose levels as before. The degree of device enhancement provided by DeEP can be selected based on the type of ERCP procedure, improving the visibility of guidewires, metal stents, and stone-removing baskets as well as the visibility of guidewires within contrast medium and devices overlapping bone structures.

4. ERCP Cases Using DeEP

Case 1

A case of localized benign bile duct structure was treated by placing a metal stent at the region of

Fig.2 SONIALVISION G4 LX and Control Console

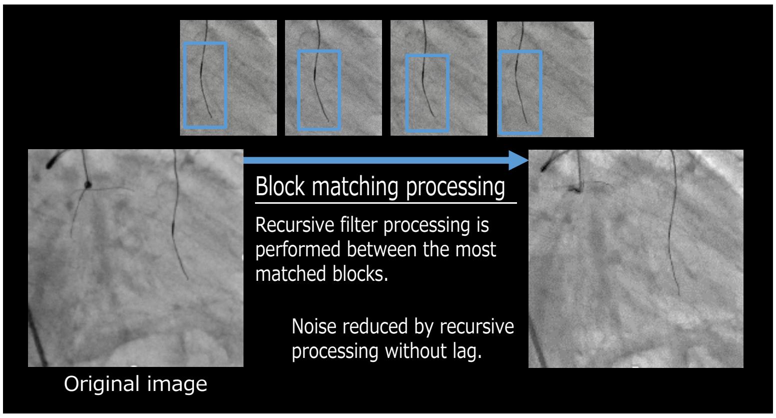


Fig.3 Motion Tracking Noise Reduction

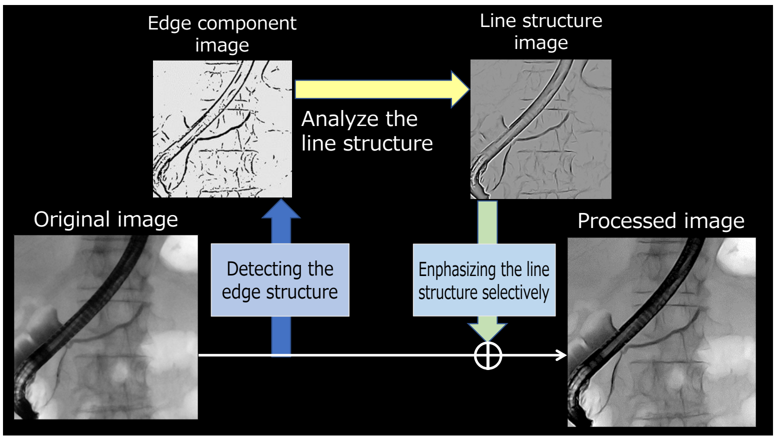


Fig.4 Object detected Edge Enhancement

stricture. Using DeEP allowed for a clear view of the entire stent, ensuring the stent remained in the optimum location during deployment **(Fig. 5)**. The view magnification feature was particularly useful during stent deployment **(Fig. 6)**, as it gave the operator clear images to reference when making fine adjustments to the position of the stent. The stent used in this case was a 10 mm × 3 cm BONASTENT M-Intraductal with a dumbbell-like shape marketed by Medico's Hirata Inc.

Case 2

A patient was referred to our hospital with recurrent pancreatitis due to incomplete pancreas divisum. Following a minor papillotomy, a pancreatic duct stent was inserted from the accessory pancreatic duct. In the past, pancreatic stents were not visualized clearly, but DeEP made the peripheral end of the stent easier to distinguish and ensured a successful stent placement **(Fig. 7)**. The pancreatic stent used was a 7 Fr × 8 cm pigtail plastic stent

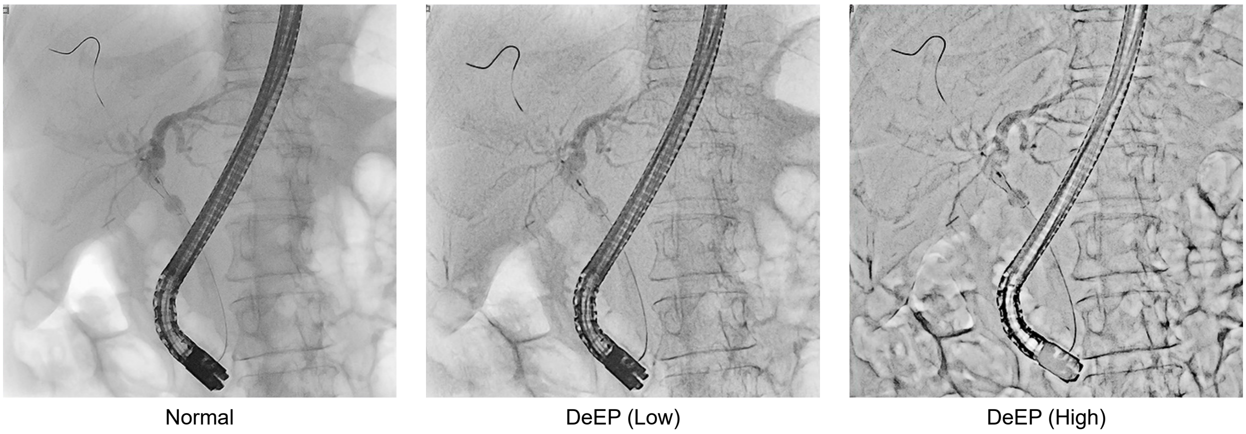


Fig.5 Placement of metal stent at localized benign bile duct stricture. Using DeEP for a clear view of the entire stent.

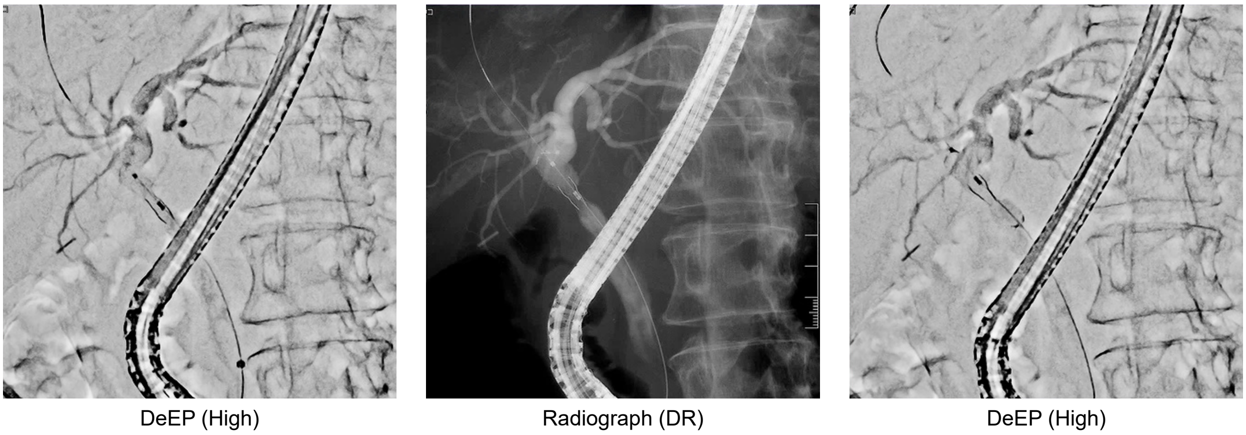


Fig.6 Field magnification image provides a clear view of the stent position during deployment.

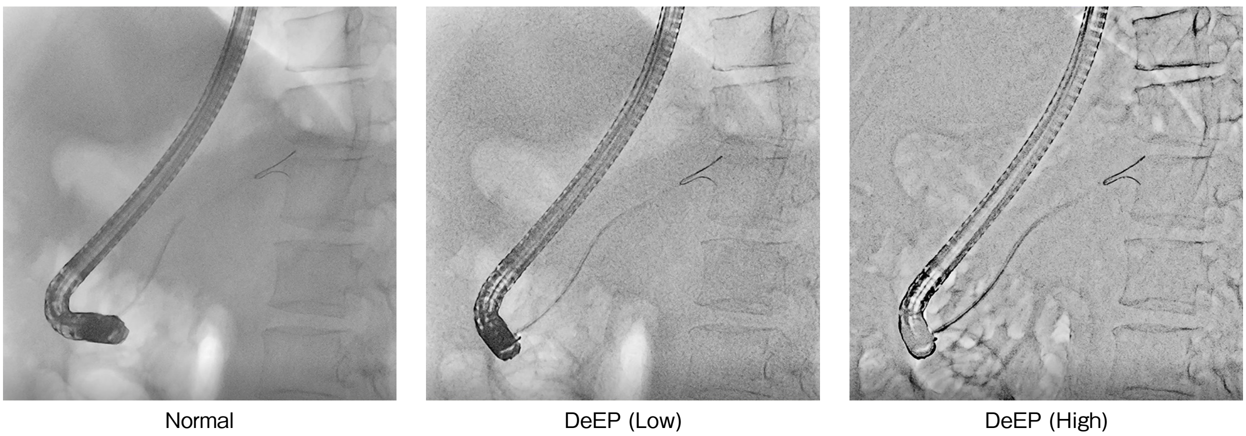


Fig.7 Using DeEP for a clearer visualization of the peripheral end of the pancreatic stent.

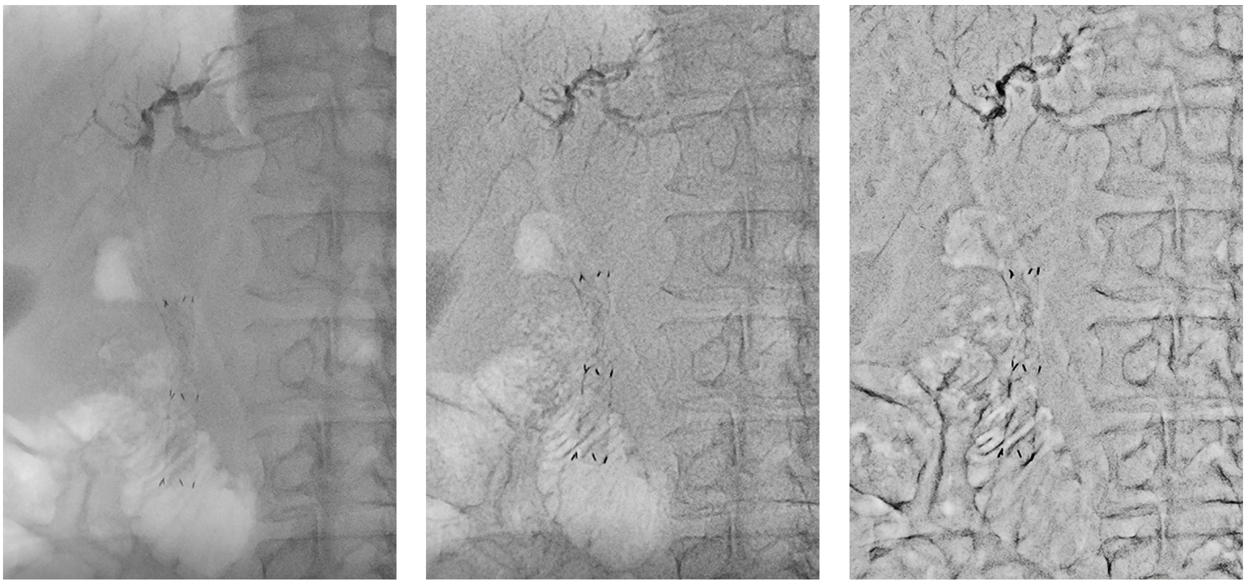
(Zimmon Pancreatic Stent Sets) marketed by Cook Medical Japan.

Case 3

A metal biliary duct stent was placed for obstructive jaundice caused by sclerosing cholangitis. DeEP made it easy to determine where to commence stent deployment and to confirm the state of stent deployment **(Fig. 8)**. The stent used was a 10 mm × 6 cm fully covered metal stent (HANAROSTENT Biliary Full Cover) marketed by Boston Scientific. When ascertaining the final morphology of the deployed stent, the high-contrast DeEP setting (DeEP (High)) provided a relatively clear visualization of the positional relationship between the stent and the intestinal tract **(Fig. 9)**.

DeEP (High) DeEP (High) DeEP (High)

Fig.8 Placement of a metal biliary duct stent for obstructive jaundice. Using DeEP for easy determination of where to commence stent deployment and verification of stent deployment.



Normal DeEP (Low) DeEP (High)

Fig.9 Using DeEP (High) to ascertain the final morphology of the deployed stent.

5. In Summary

Revision of the “Regulation on Prevention of Ionizing Radiation Hazards” by the Ministry of Health, Labour and Welfare Japan has resulted in stricter controls on dose exposure levels. In this context, the SONIALVISION G4 LX equipped with SCORE PRO Advance can provide high image quality at low dose levels, and in our experience, DeEP device enhancement processing also improves visualization during ERCP procedures. Nevertheless, several issues remain unaddressed, such as some devices still lacking visual clarity and inadequate processing of lower priority structures such as air and bone. We look forward to seeing what further improvements can be made to the equipment.

Reference

1) Tasuku Saito, Development of the SONIALVISION G4 LX edition, MEDICAL NOW, No. 87, 30-34, 2020

R/F

Tomosynthesis Applications in Thoracic Imaging —Utility in Early Diagnosis of Lung Cancer—

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Simantocho Taisho Shinryosho

Takeshi Okawa

1. Introduction

Shimantocho Taisho Shinryosho (Taisho Clinic) is located in the Taisho District of Shimanto town, Kochi Prefecture. Taisho District itself is situated in the middle reaches of the beautiful Shimanto River and is home to 2,501 residents (of 17,500 in Shimanto town), 46.7 % of whom are elderly (41.6 % male and 51.4 % female as of February 2022).

Fig.1 View of Taisho Clinic

Taisho Clinic has 19 beds **(Fig. 1)** and offers emergency medical services 365 days a year. In March 2021, a SONIALVISION G4 series system (Shimadzu Co.) was installed in the clinic, adding to an existing 16-slice CT scanner and ultrasound system. As well as conventional fluoroscopic examinations, the SONIALVISION G4 series system can perform tomosynthesis (digital tomography), slot radiography (long view radiography), general radiography, and bone mineral density (BMD) measurements (of the lumbar spine and femoral neck).

As a clinic treating a high proportion of elderly patients, tomosynthesis is very useful for diagnosing disorders in the thoracic region as well as orthopedics because it offers a more accurate view of pathological conditions than general radiography and can pinpoint sites for examination at radiation doses one-third to one-tenth that of CT[1), 2), 3)].

In recent years, The Japan Ministry of Health, Labour and Welfare, The Japan Association of Radiological Technologists, the Nuclear Safety Technology Center (NUSTEC), and various medical institutions have pursued various initiatives to reduce radiation exposure among health care workers and patients amidst a growing interest in reducing radiation exposure levels. At Taisho Clinic, we also place the utmost priority on reducing the exposure of patients and medical personnel to radiation. We are using the general radiography and tomosynthesis functions of the SONIALVISION G4 series system effectively to perform imaging with as little positioning support as possible, so that radiation exposure to medical personnel who may need to reposition elderly patients during examinations can be minimized. Reducing the number of positional changes and minimizing uncomfortable positioning of the extremities have also made examinations less burdensome and more comfortable for patients. In some cases, we skip general radiography and perform tomosynthesis when examining the lungs and bone fractures in various sites. Tomosynthesis is also quick and causes less pain to elderly patients and is effective for diagnosis.

2. Using Tomosynthesis in the Thoracic Region

Between March 2021 and the end of March 2022, Taisho Clinic performed a total of 115 tomosynthesis imaging procedures, of which 40 were in the thoracic region.

In order to verify whether tomosynthesis (TOMOS) can be used for clinical evaluation in the thoracic region at our clinic, patients first underwent plain chest radiography (digital chest radiography), after which tomosynthesis was used to evaluate cases with suspicious findings.

In this article, we compare digital chest radiography, chest CT, and chest tomosynthesis for early diagnosis of lung cancer and other thoracic conditions and report on the clinical usefulness of each imaging technique in the thoracic region (ultrasound and digital radiography were compared for hairline rib fractures).

Between March 2021 and the end of March 2022, Taisho Clinic used tomosynthesis to image the thoracic region in 40 patients comprised of 14 males and 26 females aged between 28 and 96 years (mean age: 76.5 years).

Digital chest radiographs, tomosynthesis images, CT images, and ultrasound images were evaluated on a PACS workstation. Images were examined for

10 findings: (1) ground-glass opacities, (2) infiltrative shadows, (3) nodular shadows, (4) changes in pulmonary vascular shadows, (5) bronchiole wall thickening, (6) interlobular septa thickening, (7) reversed halo signs, (8) rib fractures (including the sternum and costal cartilage), (9) honeycomb lung, and (10) pleural thickening **(Table 2)**.

Table 1 Clinical Data on Tomosynthesis in the Thoracic Region (No. of Cases)

Bronchitis, asthma	4
Pneumonia (including acute and obsolete)	6
Pleuritis	1
Metastatic lung cancer (esophageal cancer)	1
Chronic heart failure	2
Thoracic empyema	1
COPD	6
Rib fracture	8
Costal cartilage fracture	1
Sternum fracture	1
Tortuosity of the thoracic aorta	1
Lung cancer (stage IA2)	1
Esophageal hiatal hernia	2
Pneumothorax	1
Heart valve disease	1
Benign lung tumor	19
Other, no findings	7

Table 2 Image Evaluation

(1)	Ground-glass opacity
(2)	Infiltrative shadow
(3)	Nodular shadow
(4)	Changes in pulmonary vascular shadows
(5)	Bronchiole wall thickening
(6)	Interlobular septa thickening
(7)	Reversed halo signs
(8)	Rib fracture (including the sternum and costal cartilage)
(9)	Honeycomb lung
(10)	Pleural thickening

3. Results of Image Evaluation

Table 3 Results of Image Evaluation (No. of Cases with Confirmed Visualization)

Image Evaluation		DR	TOMOS	CT
(1)	Ground-glass opacity	2	4	4
(2)	Infiltrative shadow	2	4	4
(3)	Nodular shadow	3	19	19
(4)	Changes in pulmonary vascular shadows	0	4	8
(5)	Bronchiole wall thickening	0	4	6
(6)	Interlobular septa thickening	0	2	7
(7)	Reversed halo signs	0	3	3
(8)	Rib fracture (including the sternum and costal cartilage)	4	8	9 by ultrasound (no CT evaluation)
(9)	Honeycomb lung	2	5	6
(10)	Pleural thickening	6	12	12

3.1 Ground-Glass Opacity

Ground-glass opacity is often seen in cases of interstitial pneumonitis. Pathologically, ground-glass opacity is defined as a pale shadow due to exudate or secretions in some areas of the alveoli or interstitium while air is retained in the alveoli. Tomosynthesis is less accurate than CT at the margins of the lungs that overlap the ribs, but accuracy can be increased by adjusting the viewing angle of the reconstructed image or by reducing the slice pitch.

Ground-glass opacities are non-specific findings seen with both parenchymal (alveolar epithelial cell and alveolar space) lesions and interstitial lesions, and tomosynthesis is far superior to digital chest radiography in detecting ground-glass opacities in the early stages of COVID-19 and other pathologies[4)].

3.2 Infiltrative Shadow

Infiltrative shadow (consolidation) is principally seen in cases of parenchymal pneumonia. Healthy alveoli are full of air and appear black in radiographs while an infiltrative shadow appears pure white and indicates a problem in the lung parenchyma such as displacement of air from alveoli by exudate, secretions, or sputum. Tomosynthesis and CT are more comparable in their ability to visualize infiltrative shadows than ground-glass opacities, and tomosynthesis is far superior to digital chest radiography in detecting infiltrative shadow lesions. Tomosynthesis in the thoracic region should also be capable of visualizing small ground-glass opacities and small infiltrative shadows that cannot be visualized by digital chest radiography.

3.3 Nodular Shadow

Nodular shadows are often identified when digital chest radiography or CT is performed in asymptomatic patients during medical checkups or for coughs or similar symptoms. The identification of nodular shadows, ground-glass opacities, and band-like opacities is extremely important for the imaging-based diagnosis of lung cancer. However, benign lesions such as post-inflammatory changes and intrapulmonary lymph nodes also form nodular shadows.

Compared to digital chest radiography, tomosynthesis is reported to be 37 % more sensitive at detecting pulmonary nodules 10 mm or larger in size[2)].

Digital chest radiography often misses nodules that are around 10 mm in size when they overlap bony structures in the thoracic region, overlap blood vessels, are located behind the diaphragm or around the heart, or when there is ossification of costal cartilage. Tomosynthesis offers clear visualization of nodules 10 mm and smaller regardless of any overlap with other structures.

At Taisho Clinic, we have seen similar results from CT and tomosynthesis in visualizing nodular shadows, with 19 cases confirmed by CT, 19 by tomosynthesis, and 3 by digital chest radiography **(Table 3)**. Digital chest radiography is clearly of limited use in visualizing small nodular shadows, while tomosynthesis provides clear visualization of granular shadows, mass shadows, and nodular shadows 3 to 5 mm in size (**Fig. 2 to 7**, all from the same patient).

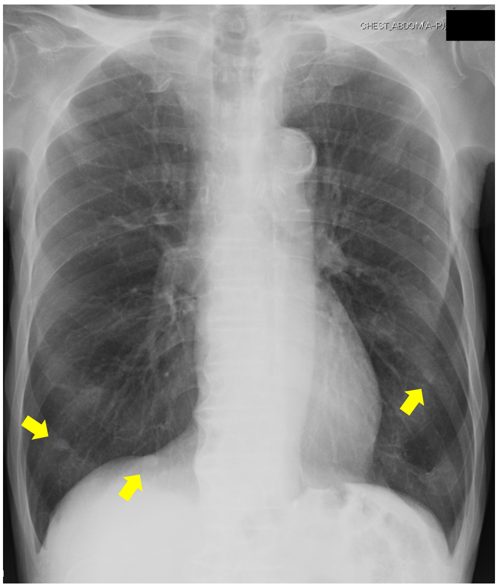

Fig.2 80-year-old male with lung metastases after esophageal cancer surgery. Nodules 9 mm and smaller are difficult to distinguish on digital chest radiographs.

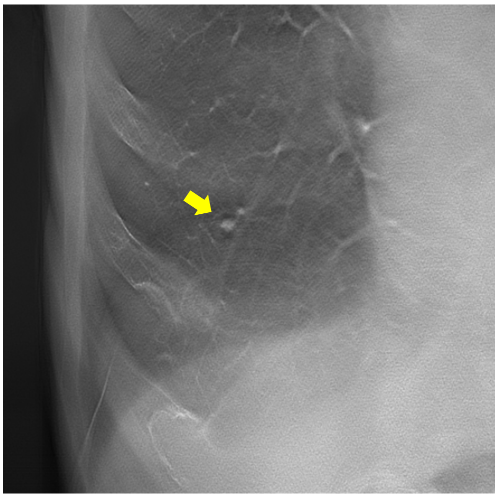

Fig.3 Esophageal cancer with lung metastasis. TOMOS image showing 3-mm nodule in right inferior lobe.

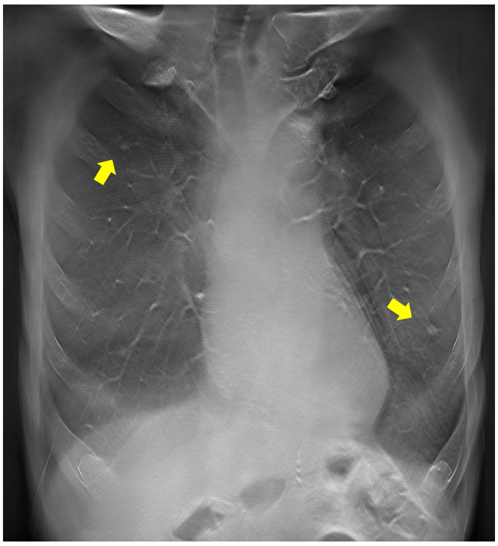

Fig.4 Esophageal cancer with lung metastasis. TOMOS image showing 4-mm nodule in right superior lobe and 5-mm nodule in left inferior lobe.

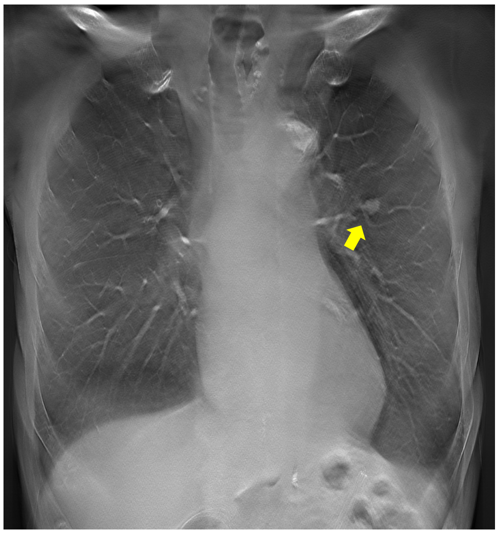

Fig.5 Esophageal cancer with lung metastasis. TOMOS image showing 6-mm nodule in left superior lobe.

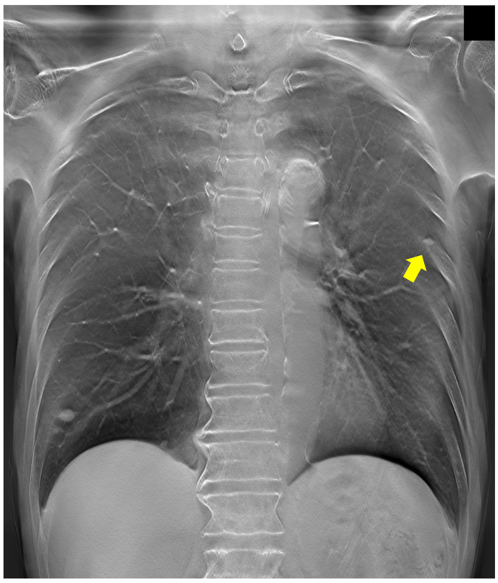

Fig.6 Esophageal cancer with lung metastasis. TOMOS image showing 9 and 4-mm nodules in right inferior lobe and 4-mm nodule in left superior lobe.

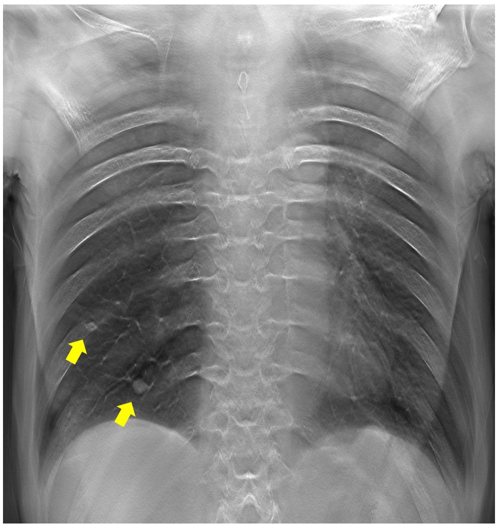

Fig.7 Esophageal cancer with lung metastasis. TOMOS image showing 5 and 6-mm nodules in right inferior lobe.

Although CT has overtaken digital chest radiography as the principal imaging modality of choice for imaging-based diagnosis of shadows in early-stage lung cancer, CT also comes with issues such as increased imaging times and increased radiation exposure. When we used tomosynthesis for diagnostic imaging of early-stage lung cancer, breath-holding times were reduced due to 2.5-second high-speed scanning times, and image data reconstruction was quicker than CT. Tomosynthesis is also reported to use one-third to one-tenth the radiation dose of CT (dose varies by CT scan conditions)[1), 2), 3), 4)]. Replacing digital chest radiography with thoracic tomosynthesis for screening applications should help the early diagnosis and treatment of lung cancer and save numerous lives **(Fig. 8, 9)**.

3.4 Changes in Pulmonary Vascular Shadows

Pulmonary vascular shadows are changed by pulmonary lesions. These changes are identified by close examination of images for the thickness and number of pulmonary vessels. Thinning of a pulmonary vessel suggests a condition that causes reduced pulmonary blood flow, and attenuation of a pulmonary artery shadow is the main thoracic finding of chronic pulmonary arterial embolism. Because tomosynthesis provides clear visualization of the pulmonary vasculature regardless of overlapping blood vessels above or below the vessel of interest, abnormal pulmonary vascular shadows and vascular changes caused by air trapping and hyperinflation of the lungs are visible in tomosynthesis images, and since tomosynthesis images can be interpreted using the same principles as digital chest radiographs and CT images, tomosynthesis offers a more convenient method for evaluating pathophysiology based on lung volume, lung permeability, and pulmonary vascular shadows.

3.5 Bronchiole Wall Thickening

The main airways (bronchi) of the lungs branch off into smaller and smaller passageways. The bronchioles

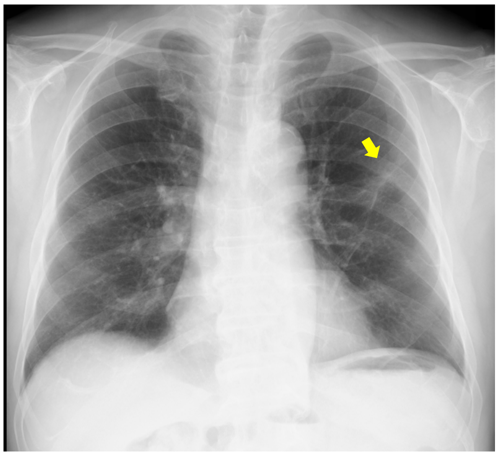

Fig.8 Digital Chest Radiograph Showing trabecular shadow in Left Superior Lobe in Patient with Lung Cancer

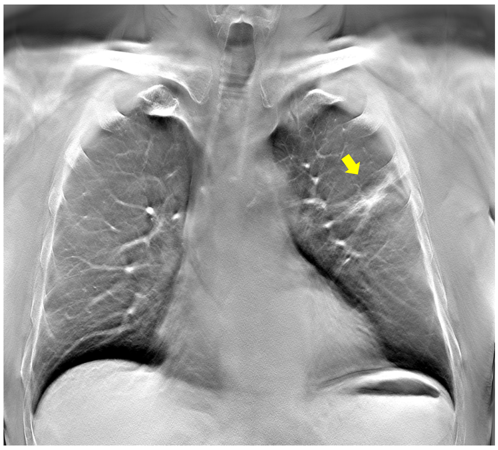

Fig.9 TOMOS Image Showing Stage I A2 Lung Cancer in Left Superior Lobe

begin where these bronchial airways narrow to an inner diameter of around 1 mm or smaller and end just before the respiratory bronchioles that lead to alveolar structures. Bronchioles also lack the supporting cartilage skeletons found in the bronchi.

High-resolution CT is used to evaluate bronchial asthma and bronchiolitis, but we have also been able to evaluate bronchial wall thickening with tomosynthesis. Tomosynthesis can also visualize the tree-in-bud pattern of centrilobular nodules.

3.6 Interlobular Septa Thickening

Thickening of the interlobular septa is also a common finding. In digital chest radiography, this thickening is visualized as Kerley lines. Causes of interlobular septa thickening include edema in the interstitium caused by pulmonary edema and cancerous lymphangiopathy and fibrosis in the interstitium caused by interstitial pneumonitis. Although inferior to high-resolution CT (HRCT), interlobular septa thickening has also been visualized by tomosynthesis.

3.7 Reversed Halo Sign

The reversed halo sign was once considered unique to organizing pneumonia (OP), but this association has become less definitive as the reverse halo sign was also observed in association with many other conditions including infectious diseases and pulmonary embolism. We confirmed the reversed halo sign in both lungs by tomosynthesis as a finding of COPD **(Fig. 10, 11)**.

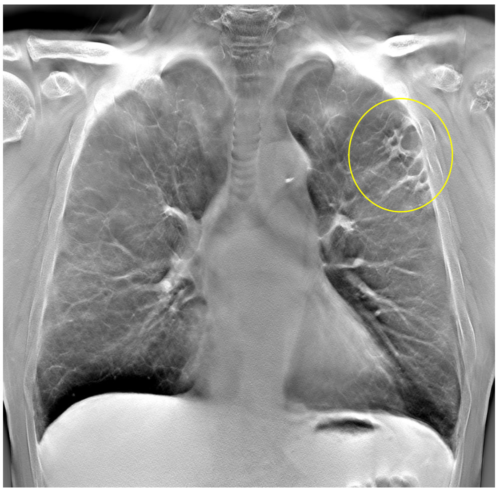

Fig.10 Reversed Halo Sign in Left Superior Lobe

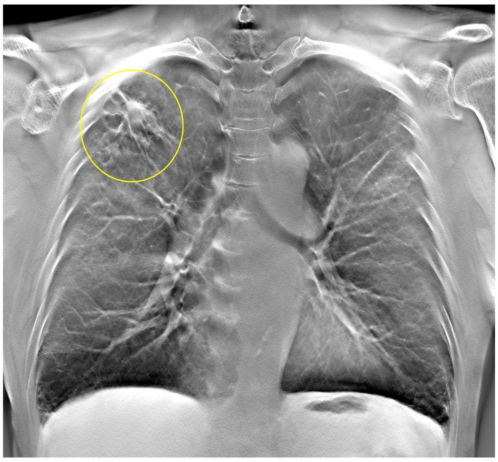

Fig.11 Reversed Halo Sign in Right Superior Lobe (Same Patient as **Fig. 10**)

3.8 Rib Fracture (Including Sternum and Costal Cartilage)

Physicians sometimes have difficulty diagnosing fragility microfractures in patients with osteoporosis, even when images are acquired by radiological technologists with extensive experience in digital radiography. Tomosynthesis has recently become a very useful diagnostic tool in orthopedic medicine and is extremely good at detecting fractures in the thoracic region otherwise identified as suspected fractures by digital radiography. Comparing suspected fracture cases in the thoracic region by imaging technique, of 9 cases confirmed to have a fracture at our clinic, 4 were apparent on digital radiography, 8 on tomosynthesis, and 9 on ultrasound. This favorable diagnostic performance of tomosynthesis may be because the tomographic plane was adjusted parallel to the fractured rib, thereby improving the visibility of fractures. These outcomes also show how the ability to mostly eliminate bone and other overlapping thoracic structures allows tomosynthesis to visualize very small fracture lines **(Fig. 12, 13)**.

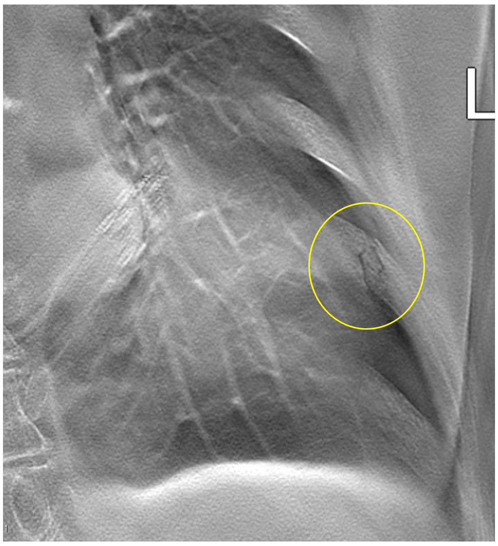

Fig.12 Obvious Rib Fracture Due to Minimal Interference from Overlapping Ribs and Other Anatomical Structures

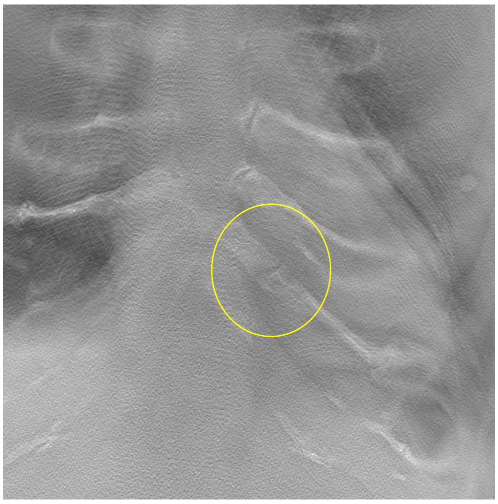

Fig.13 Costal Cartilage Fracture

3.9 Honeycomb Lung

Honeycomb lung is seen in cases of interstitial pneumonitis and appears as a mesh-like shadow on CT. Honeycomb lung is defined as clustered, air-filled cysts typically 3 to 10 mm in diameter, usually subpleural and with clearly defined walls. Honeycomb lung forms from a combination of collapsed alveoli and enlargement of alveolar ducts and alveolar lumen, indicates the presence of fibrotic changes, and can also be evaluated using tomosynthesis.

3.10 Pleural Thickening

Pleural thickening is sometimes revealed by digital chest radiography examinations performed during medical checkups. Although most instances are not pathogenic, pleural thickening is also commonly associated with health problems linked to asbestos inhalation in carpenters, plumbers, house wreckers, and auto mechanics and cannot be ignored. When inhaled, asbestos fibers become deposited in alveoli just below the pleura where they irritate the pleura and cause pleural thickening. This pleural thickening is localized and formed of pleural plaques, which often

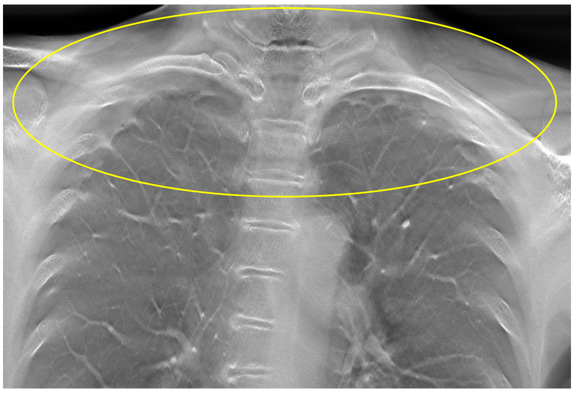

Fig.14 Well-Visualized Pleural Thickening in the Lung Apex

include calcifications on imaging. Pleural thickening is also a very common complication of malignancies such as pleural mesothelioma and lung cancer, and can also be caused by tuberculosis in the apex of the lung. Our experience shows that tomosynthesis detects pleural thickening at a higher rate than digital chest radiography, and an equivalent rate to CT **(Fig. 14)**.

4. Summarizing the Advantages of Tomosynthesis

- Tomosynthesis performs similarly to CT and is superior and more accurate at detecting lesions in the thoracic region compared to digital chest radiography.
  Although digital chest radiography is used to diagnose lung cancer, small pulmonary nodules are often overlooked by digital chest radiography when they overlap anatomical structures such as the bones of the thorax, the heart, and blood vessels in the mediastinum. This issue can also be exacerbated in cases when digital chest radiographs are only acquired from a single direction (frontal view) rather than two directions.
- Compared to digital chest radiography, tomosynthesis is less affected by overlapping anatomical structures and is reportedly 37 % more sensitive in detecting pulmonary nodules 10 mm or larger[1]. At Taisho Clinic, we have found tomosynthesis and CT perform equally well in providing good visualization of pulmonary nodules 10 mm or smaller.
- Alongside digital radiography, CT is also an important imaging technique for chest lesion examinations. Recent years have seen the use of low-dose mode CT in medical checkups and other applications, though exposure levels from CT remain high enough to pose an issue.
  Tomosynthesis can reduce radiation exposure significantly compared to CT, using radiation doses around one-tenth to one-third that of CT[1), 2), 3)].
- Shimadzu's proprietary technology allows tomosynthesis to be performed in high-speed 2.5-second scans and still produce clear images with no signs of movement, even in elderly patients who have difficulty holding their breath.
- Tomosynthesis can also be performed in semi-sitting and supine positions for patients who have difficulty maintaining a fully upright posture.
- Tomosynthesis can be used for imaging in the thoracic region and orthopedic applications with the patient standing or lying.
- Tomosynthesis is a quick and painless imaging technique that reduces the burden on elderly patients and patients who have difficulty changing positions, which is also effective for diagnosis.

5. Conclusion

As a medical institution that caters to a largely elderly population, we have found tomosynthesis useful for examining the whole thoracic region, including in patients with skeletal abnormalities or patients with a rounded or kyphotic spine that can make imaging or image interpretation a challenge when using digital chest radiography. Many of our elderly patients who undergo tomosynthesis are pleased with the undemanding nature of the examination, pleased the breath-holding time is shorter than CT, and pleased the examination is completed in only a few seconds.
Tomosynthesis is simple to implement, quick, generates low levels of exposure, and produces high-quality images of areas of interest that are suitable for evaluation. The effective application of tomosynthesis with a proper understanding of its utility allows examinations to be performed without unnecessary repositioning of the patient, eliminates patient discomfort and pain, and reduces unnecessary use of CT for lower radiation exposure. Tomosynthesis also incurs fewer national health insurance points and lower medical fees than CT.
Tomosynthesis is currently not widespread use for chest imaging, but we hope this article can go some way to encourage the effective use of tomosynthesis in the thoracic region. In concluding this article, I would like to thank Shimadzu Corporation for developing the SONIALVISION G4 series system and its excellent range of features. I would also like to thank my late father who died from lung cancer.

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R/F

Device Enhancement Processing for fluoroscopy (DeEP*)

* Please contact us to check the availability of DeEP in your country.

Medical Systems Division, Shimadzu Corporation
Takeshi Shiomi

1. Introduction

Shimadzu is continuously engaged to improve the quality of fluoroscopy images and reduce radiation dose level with its R/F systems. This article presents a new feature for the SCORE PRO Advance (SPA) fluoroscopic image processing engine, which is called device enhancement processing, or DeEP. DeEP selectively enhances and improves the visibility of devices used in various kinds of examinations and procedures to (1) help procedures progress smoothly and reduced surgical stress, (2) shorten fluoroscopy times and reduced radiation doses to patients and operators, and (3) reduce the necessity of patient repositioning and lessen the burden on the patient.

2. Fluoroscopic Image Processing Engine SCORE PRO Advance

The SPA fluoroscopic image processing engine comes as standard with the SONIALVISION G4 LX edition R/F system **(Fig. 1)** and offers low radiation dose levels and image quality suitable for a variety of examinations. The fluoroscopic image processing technology in SPA was originally developed for Shimadzu angiography systems, and in addition to existing features such as recursive filter processing and multi-frequency processing, introduced two new features in (1) motion tracking noise reduction processing **(Fig. 2)** that reduces noise without generating lag images by detecting movement in localized regions of the image, and (2) object extraction-based edge enhancement processing **(Fig. 3)** that improves image sharpness by selectively processing contour structures. In the past, lag images were caused by the inter-frame processing used to reduce image noise, but SPA minimizes the influence of lag while also offering improved noise reduction and improved visibility of structures. These fluoroscopic image processing features are performed using proprietary high-speed image processing algorithms, which eliminate latency in image displaying that may impede examinations and procedures.

When integrating SPA into its R/F systems, we investigated which imaging parameters were best suited for each type of examination undertaken in the fluoroscopy room, such as detailed imaging of microstructures and natural visualization of the edges of barium contrast medium in upper and lower gastrointestinal studies, clear visualization and suppression of lag arising from guidewire movement in endoscopic retrograde cholangiopancreatography (ERCP) procedures, and

Fig.1 SONIALVISION™ G4 LX edition

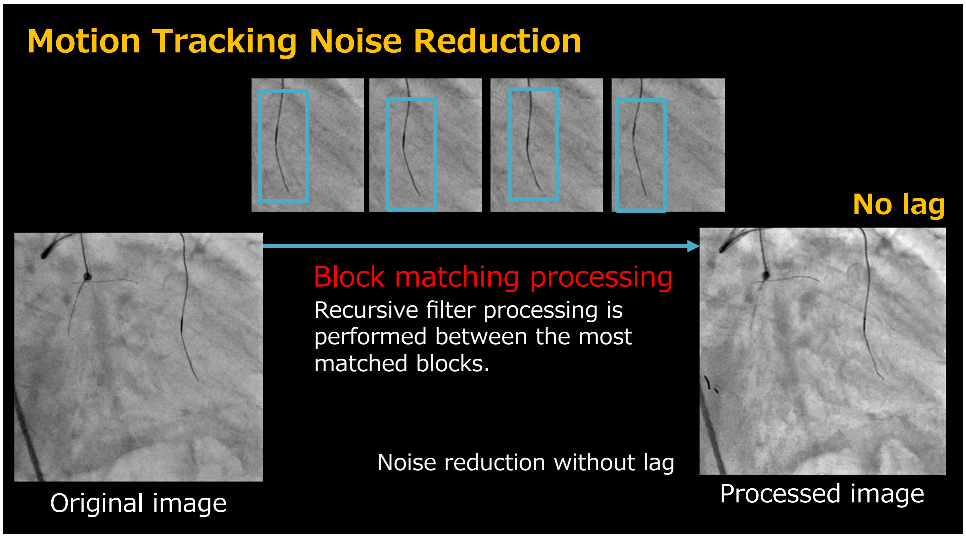


Fig.2 Motion Tracking Noise Reduction

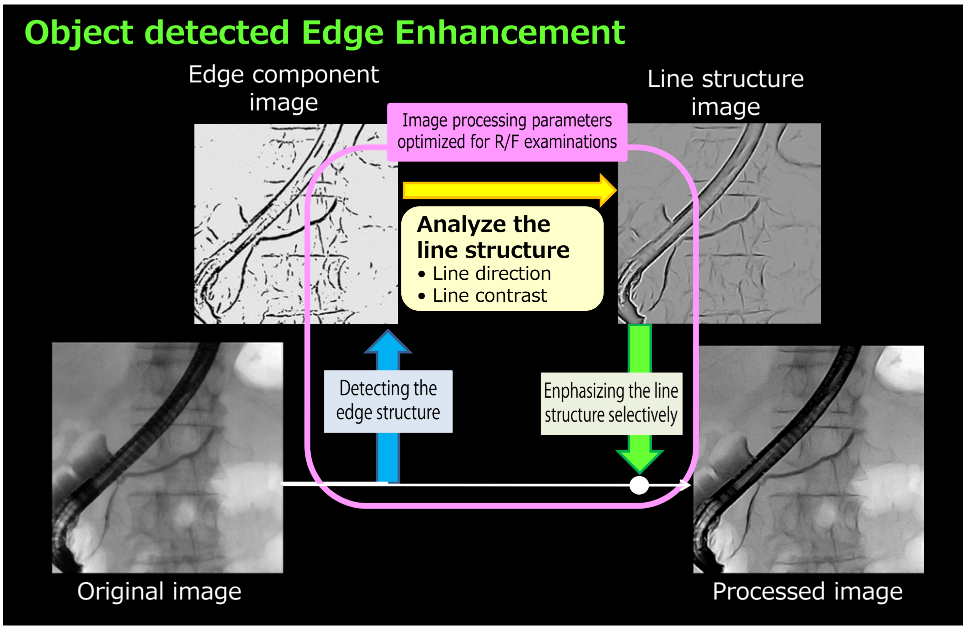


Fig.3 Object Extraction-based Edge Enhancement

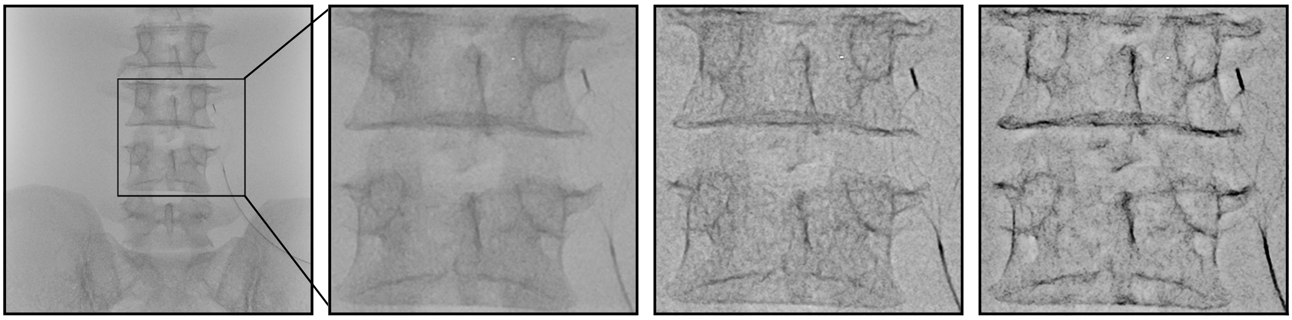
reduced granularity at low radiation dose images for pediatric or gynecological studies. The improvements in fluoroscopy image quality provided by SPA allowed images to be acquired at around 40 % of the radiation dose level of previous methods while maintaining image quality. The significant lag reduction achieved by SPA also allowed pulse rates to be lowered without loss of visibility for even lower radiation dose levels in certain fluoroscopic examinations and procedures.[1, 2, 3)]

3. Device Enhancement Processing (DeEP)

DeEP was developed by re-engineering the object-extraction edge enhancement algorithm in SPA for devices used in ERCP procedures. Based on the low-noise/low-lag fluoroscopy images produced by the motion tracking noise reduction feature in SPA, the target frequency bandwidths and density difference thresholds in extraction of edge structures were examined, and the performance for detection and imaging of thin devices or devices made of materials with low radiopacity was increased to achieve higher device visibility without increasing the fluoroscopic X-ray dose.

Two types of DeEP fluoroscopy images are available in addition to SPA fluoroscopy images that already have a proven track record in the field. DeEP_High images are primarily intended for extracting and enhancing thin devices and DeEP_Low enhances devices while preserving background contrast information including contrast media and bones. Operators can switch between these DeEP fluoroscopy image settings during an examination to suit the procedure or point in the procedure. Images of a simulated ERCP setup **(Fig. 4 and Fig. 5)** show that DeEP improves the visibility of a stone retrieval basket and guidewires surrounded by contrast medium, including parts of these devices that overlapped bone. Evaluation in clinical cases has shown that fluoroscopy images enhanced by DeEP provide the following benefits during actual clinical ERCP procedures: faster device manipulation due to improved guidewire visibility, improved marker visibility that helps when deciding the position of stent placement and verifying stent deployment, easier confirmation of stent and mesh deployment, and easier monitoring of stone crushing.[4)]

Images in simulation of peripherally inserted central catheter (PICC) setup **(Fig. 6)** were acquired to examine the feasibility of applying DeEP to other than ERCP examinations and procedures. The images show that DeEP improved the visibility of a guidewire overlapping the mediastinum. DeEP also



(a) SPA fluoroscopy image **(b)** SPA fluoroscopy image **(c)** DeEP_Low fluoroscopy image **(d)** DeEP_High fluoroscopy image

Fig.4 Example DeEP fluoroscopy images (1). Stone retrieval basket (Ni-Ti) placed on lumbar phantom (PBU-3).
(a) SPA fluoroscopy image (full 12-inch field of view); **(b)**, **(c)**, and **(d)** are cropped from the center of image **(a)**. "Normal Dose" fluoroscopy dose mode used in all images.

(a) SPA fluoroscopy image **(b)** SPA fluoroscopy image **(c)** DeEP_Low fluoroscopy image **(d)** DeEP_High fluoroscopy image

Fig.5 Example DeEP fluoroscopy images (2). Guidewires placed over lumbar phantom and tubes filled with contrast medium.
(contrast medium: 300 stock solution, tube id: 4, 6, and 9 mm, guidewire od: 0.014 inches, lumbar phantom: PBU-3).

(a) SPA fluoroscopy image **(b)** DeEP_Low fluoroscopy image **(c)** DeEP_High fluoroscopy image

Fig.6 Example DeEP fluoroscopy images (3). Guidewire placed over chest phantom.
(guidewire O.D.: 0.025 inches, chest phantom: N-1).

increases influence of dynamic range compression, which should prove useful for reducing the influence of thoracic air space and abdominal intestinal gas during fluoroscopy.

4. Conclusion

This article introduces the DeEP device enhancement processing feature included in the SONIALVISION G4 LX edition. The improvements in device visibility achieved by DeEP is expected to (1) help procedures progress smoothly and reduced surgical stress, (2) shorten fluoroscopy times and reduced radiation doses to patients and operators, and (3) reduce the necessity of patient repositioning and lessen the burden on the patient. While taking on valuable feedback from a diverse range of health care professionals, We will continue its research into improving the visibility of all kinds of ERCP devices and applications for this technology in other than ERCP examinations and procedures, continuing to evolve its products for better medical care.

Finally, I would like to thank everyone at the Department of Gastroenterology, digestive Disease Center at Kyoto Katsura Hospital, the Department of Radiology at Kyoto Katsura Hospital, and the Department of Endoscopy at The Jikei University School of Medicine for their valuable cooperation and advice regarding the review of DeEP fluoroscopy images.

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Our Experience with the MobileArt Evolution MX8 Version Mobile X-Ray System

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Kanna Yamamoto, Takahiro Kaichi, Kenji Koyama

1. Introduction to Hattori Hospital

Hattori Hospital is located in Miki City, which is in Harima Area and lies close to Kobe City in south-central Hyogo Prefecture. With a population of around 80,000 people, Miki City is known both for a long history of metalworking and for its golf courses, boasting the largest number in West Japan. Since establishing itself in Miki City, Hattori Hospital has built a long history of community medical services as a core hospital in the region.
The hospital opened as Hattori Surgical Clinic in 1967 with just 7 beds, and since 1986 has been expanding its bed numbers and specialist departments. A dialysis clinic was opened in Higashi-Kakogawa in 2007, an MRI machine was installed in 2008, and a rehabilitation unit was opened in 2016. Today, the hospital has 129 general ward beds (including 36 in the rehabilitation unit and 18 integrated community care beds), 50 convalescent ward beds, and 12 medical departments, is a designated emergency hospital, a medical institution for selected diseases, is appointed by Miki City as a medical checkup center, and its department of surgery and many other departments support community health care. Hattori Hospital also uses the Kita-Harima Kizuna Net system to access and share the medical data of consenting patients with neighboring hospitals (Fig. 1).

2. Backdrop to System Procurement and Model Selection

The hospital performs around 500 mobile X-ray examinations each year in its operating rooms and wards. The previous mobile X-ray system used by Hattori Hospital was not made by Shimadzu and first entered into operation in 2004. The hospital chose to replace the system in 2021, after 18 years of use and associated wear and tear. Demonstration units from several manufacturers were put through their paces and the MobileArt Evolution MX8 Version mobile X-ray system stood out as the most promising candidate due to its user-friendliness and superior ease of use. Many of the radiological technologists at Hattori Hospital struggle with operating heavy medical equipment, and the Shimadzu mobile X-ray system features a collapsible column that improves visibility during transport, power-assist functionality for easy driving, and dual motor technology for small turning circles and reduced physical stress for technologists. These features combine with many other aspects of the Shimadzu mobile X-ray system to significantly reduce the burden on hospital technologists. Hattori Hospital also did not have a radiology information system (RIS) at the time, and the Shimadzu MobileArt Evolution MX8 Version mobile X-ray system (Fig. 2) was installed, which can be applied to future RIS installations.

Fig.1 Hattori Hospital

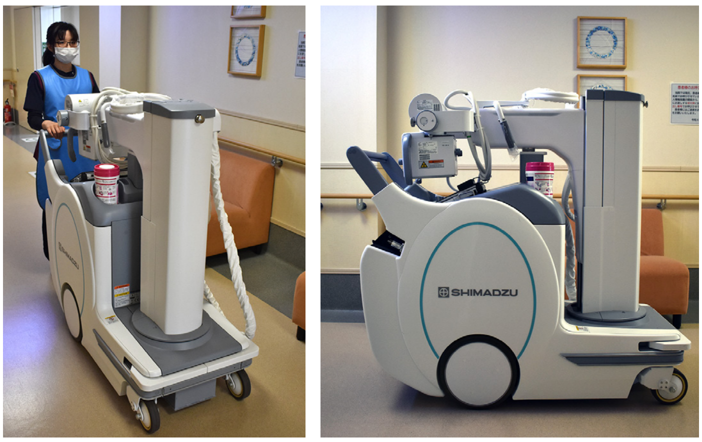

Fig.2 Mobile Art Evolution MX8 Version

3. Imaging Systems and Infrastructure at Hattori Hospital

Hattori Hospital operates an electronic medical records system (hospital information system [HIS]) (updated in February 2022) from Software Service, a PACS and image viewers from Konica Minolta, and FPDs also from Konica Minolta (two 17 × 17 inch, one 14 × 17 inch, and one 10 × 12 inch AeroDR FPDs). The hospital also uses a laptop computer with its mobile X-ray system and its FPDs are shared use with general radiography. A wireless LAN was also installed in the hospital when the HIS was updated, allowing images and radiology orders to be sent and received instantaneously from wards and operating rooms, significantly modifying and improving the workflow.

4. Workflow of Operations using Mobile X-ray System

Most examinations using the mobile X-ray system are performed in wards, operating rooms, and emergency rooms.

(1) A physician submits a radiology order via the HIS.

(2) Patient data is retrieved from the RIS, and the radiographic Information and the patient's location in the hospital where the examination will take place are confirmed.

(3) As the MobileArt Evolution MX8 Version has no built-in DR system, a laptop is loaded onto the Shimadzu mobile X-ray system along with the appropriate FPD and transported to the patient.

(4) Before X-ray exposure, patient data and the radiographic Information are verified once more against the bar code on the patient's wristband.

(5) After X-ray exposure, the images are viewed, image processing is applied, and images are immediately sent to PACS via the hospital wireless LAN.

(6) To prevent patient misidentification, examinations are ended as soon as imaging is complete.

5. Overview of MobileArt Evolution MX8 Version

The MobileArt Evolution MX8 Version is equipped with a collapsible column that is collapsed to a height of 1,270 mm during transport, a 12.5 kW high voltage power unit, an X-ray tube, a collimator, and a range of other optional products. The main cart has a compact design at just 560 mm wide and 1,285 mm high. The collapsible column rotates through a wide angular range, the telescopic arm for the X-ray tube has a maximum horizontal extension of 1,200 mm, and the maximum/minimum tube focal spot height is 2,025 mm/680 mm. The column offers a wide angular range of rotation both clockwise and anticlockwise, rotating through ±270°. The X-ray tube can swing 90° away from the column and 30° towards the column (compared to just 20° towards the column by the previous system), enabling imaging with the patient sitting or lying in small rooms. Pressing one of the "All-Free" buttons on the system gives the technologist free and unweighted control over column rotation, tube arm extension, and vertical adjustment of the X-ray tube. "All-Free" buttons are located on the top and bottom of both collimator handles, the middle of the tube arm, and on top of the cart, allowing technologists to manipulate the column and tube arm both from the collimator and from beside the column. "Inch-Mover" buttons on the collimator also move the cart forward and backward by small increments, giving technologists the ability to make fine adjustments to the irradiation field. Irradiation field adjustment controls and the irradiation field lamp switch are also duplicated on both sides of the collimator. A "soft-touch" bumper on the front of the cart is used to stop the cart upon detection of the slightest obstacle. The storage area is large enough to hold one 17 × 17 inch FPD, one 11 × 14 or 10 × 12 inch FPD, one grid, and numerous other small items, and includes a locking mechanism to prevent FPD theft. A multipurpose tray area measuring 400 × 235 mm on top of the cart serves as a convenient space for the laptop and to stow the collimator during transport. A dose calculator, included as standard, calculates and displays the dose-area product (DAP, μGym^2) after imaging based on the actual tube voltage and tube current time product, which aids in dose management.

6. Using the MobileArt Evolution MX8 Version

This section describes some aspects of the MobileArt Evolution MX8 Version that stand out as particularly useful during clinical use.

6.1 Wide Range of Column Motion and Trouble-Free Imaging

The impressive extension length of the tube arm and the large vertical and rotational range of motion of the column facilitate imaging in cramped locations or at a distance from the patient when circumstances require it. The column of the previous mobile X-ray system was 1,750 mm high and about 130 mm wide and created a partially obstructed view that required extra attention during transport. The MobileArt Evolution MX8 Version has a slightly thicker column but an approximately 500 mm lower column height, offering a much-improved view around the system including wiring and other obstacles in front of the cart. The lower column also allows positioning without interference from IV stands and curtain rails. The wide vertical range of motion also eliminates the need to adjust examination bed height, facilitating safer examination with as little unnecessary rearrangement of ventilators, biometric monitors, and other peripheral equipment as possible.

The column rotates through ±270° and the collimator has a large swing angle in both directions, offering a range of motion that facilitates axial positioning and other examinations requiring angling of the X-ray tube, even in cramped spaces **(Fig. 3)**.

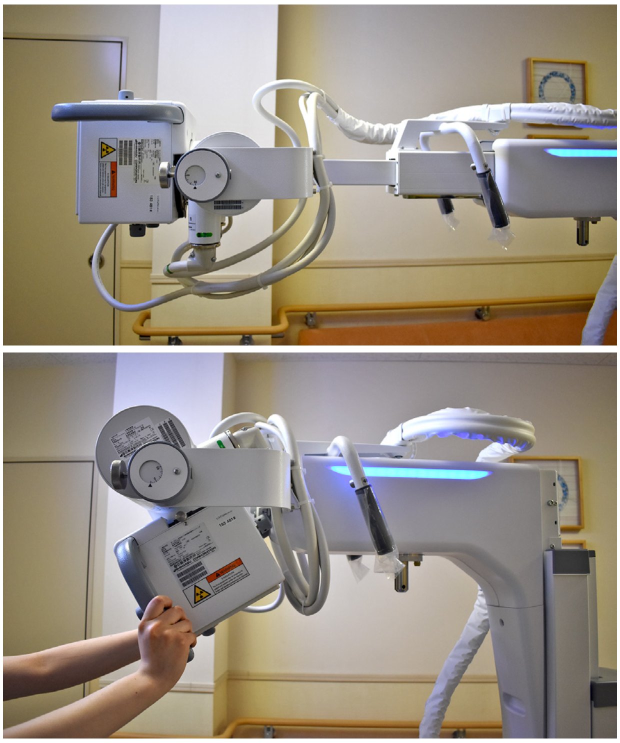

Fig.3 Large column rotation (±270°) and collimator swing angle towards and away from column

6.2 Power-Assist Functionality and Dual Motor Technology

Although the MobileArt Evolution MX8 Version weighs 440 kg, power-assist functionality ensures the cart moves smoothly and is not heavy to drive. A dual motor system also allows the cart to turn around the center of its rear axle, making turns easy even in hospital rooms and other confined spaces. These power assistance features are controlled by applying pressure to the control handle, a mechanism that offers responsive and intuitive speed adjustment and turning control.

Hattori Hospital features a number of sloped corridors between its wards that are a legacy of ongoing expansion work since 1967. While the previous mobile X-ray system quickly gained speed on downslopes and was slow and heavy on upslopes, the MobileArt Evolution MX8 Version maintains a maximum speed of around 5 km/hr with minimal input force and drives easily on both flat and sloped floors thanks to its power assistance features.

Dual motor technology also gives the system a very small turning radius, allowing the 560 mm wide unit to be positioned for examinations in corridors and narrow areas just about 700 mm wide, ensuring stable operation of the system even in limited spaces. Its “Inch-Mover” and “All-Free” controls are also very useful for system positioning. The “Inch-Mover” buttons on the collimator move the cart in 1 to 2cm increments, offering technologists a convenient way of making fine adjustments to the cart position **(Fig. 4)**. Power assistance also ensures the cart moves these increments directly forward or backward, helping to prevent contact between the cart and other medical equipment. Multiple “All-Free” buttons are also located in various locations on the system and offer light control over the column and telescopic arm while depressed. When the button is released, the column and telescopic arm are locked. An “All-Free” button is even on the underside of the tube arm within easy reach when the column is fully raised.

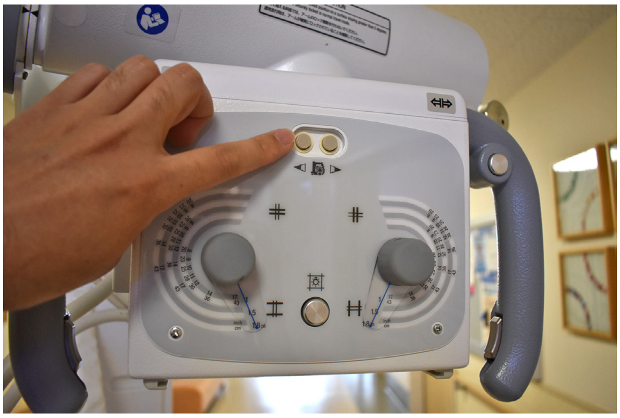

Fig.4 “Inch-Mover” Buttons. Incremental control over cart position from the collimator.

6.3 Collimator and Status LEDs

Irradiation field adjustment controls and an irradiation field lamp switch are located on both sides of the collimator, eliminating the need to rotate the collimator when setting the irradiation field. The collimator lamp also illuminates when the system is ready for imaging, which is used to check the irradiation field. The LED lights on the side of the X-ray tube support arm also change color depending on the status of the system and examination, providing an easy-to-understand visual indicator to others in the vicinity.

6.4 Wireless Hand Switch

Hattori Hospital also uses the MobileArt Evolution MX8 Version optional wireless hand switch. The previous mobile X-ray system also came with a wireless hand switch, but signals only reached the system when the hand switch was pointed directly at the signal receiver. Because many of our patients live with severe contractures, upper limbs often overlap lung fields and severe kyphosis is common. Technologists are often required to hold upper limbs away from lung fields and keep patients facing directly toward the X-ray tube during imaging, making it difficult for them to point the old hand switch directly at the receiver. For this reason, technologists often reverted to using a wired hand switch that required frequent repairs due to being used at the limit of its cord length and other general wear and tear. Signals from the MobileArt Evolution MX8 Version wireless hand switch reach the system regardless of where the hand switch is pointed and have a much wider effective range than the old system. Testing by the hospital showed that wireless signals could reach the MobileArt Evolution MX8 Version from about 10 meters away behind the closed door of the fluoroscopy room. The new wireless hand switch has proved so effective that the wired hand switch has not been used since it arrived. The wireless hand switch is also equipped with a loss-prevention alarm that Hattori Hospital has configured to sound when the hand switch is away from its holder for 10 minutes. Other facilities may wish to configure the alarm to sound sooner or later, but this feature is extremely useful and very much recommended for any facility concerned about missing equipment **(Fig. 5)**.

Fig.5 Wireless Hand Switch

6.5 Abundant Storage Space

The storage space in the Shimadzu mobile X-ray system can accommodate grids and 17 × 17 inch FPDs, items that were too large for the old mobile X-ray system **(Fig. 6)**. A multipurpose tray on top of the cart is also large enough to hold a laptop during transport and is a convenient place to carry and fill in irradiation records **(Fig. 7)**. The Shimadzu mobile X-ray system also has numerous spaces to hold small items such as wet tissues and other infection-control products **(Fig. 8)**, and used FPDs can be

Fig.6 Stores One 17 × 17 Inch FPD, One 11 × 14 or 10 × 12 Inch FPD, and One Grid

Fig.7 Multipurpose Tray with a Laptop

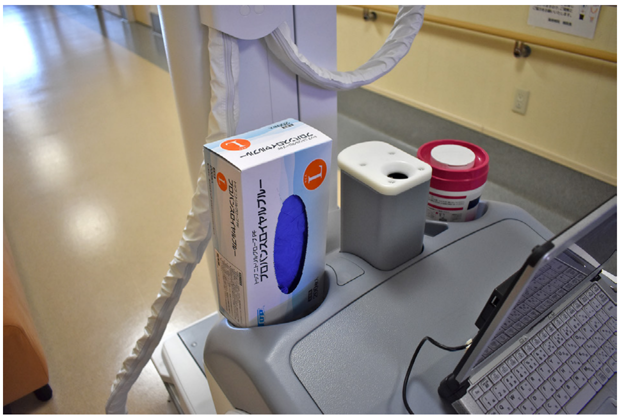

Fig.8 Small Item Storage on Front of Cart

stood upright in a slit in front of the multipurpose tray for cover removal and cleaning.

6.6 Battery Charging-Related Features

At Hattori Hospital, the old mobile X-ray system normally remained connected to the recharging cable overnight and was disconnected just before the next examination (typically, during the day shift on the following day). There were concerns that leaving the charging cable connected overnight could cause overcharging, but the MobileArt Evolution MX8 Version is equipped with an overcharge prevention feature that reduces the negative effect of extended charging on battery life. This feature is very much appreciated considering how running costs can be affected by battery life (although batteries require replacement after a given duration of use).

The MobileArt Evolution MX8 Version even has an “extra shot” feature that ensures several extra image acquisitions (the exact number depends on the imaging conditions) are still available when the battery becomes depleted during hospital rounds. Although we have yet to use this feature and prefer to avoid circumstances that may call for it, it offers a valuable failsafe.

7. Summary

The Shimadzu MobileArt Evolution MX8 Version mobile X-ray system has enabled Hattori Hospital to convert to digital radiography with comparative ease. Workflows are substantially easier thanks to numerous new features that significantly reduce both physical and technical demands on technologists. The lower column gives technologists a greater field of view, improving the visibility of IV stands and other obstacles for fewer accidents. Power-assist functionality and dual motor technology simplify transporting the system through sloping corridors and significantly reduce the physical demands on technologists during examination, such as when setting up the cart at the bedside. The MobileArt Evolution MX8 Version is more agile and maneuverable than the old system, resulting in a better user experience for both patients and technologists alike. With the MobileArt Evolution MX8 Version, routine imaging work is a more pleasant experience thanks to various thoughtful design considerations that combine to create an excellent mobile X-ray system. Nevertheless, while X-ray systems are becoming more capable and convenient with each passing year, as radiological technologists we must never lose sight of the importance of compassion and understanding in medical care, as well as our responsibility to continue improving our knowledge and expertise. The MobileArt Evolution MX8 Version is designed inside and out for convenience and ease of use, and we hope more people will have the opportunity to share our appreciation for this excellent medical imaging system.

RAD

Development of Smart DSI™ for Detecting Retained Surgical Objects

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Naomasa Hosomi

1. Introduction

Surgical items such as gauze, suture needles, or forceps are sometimes accidentally left inside the patient's body during invasive procedures. These types of medical incidents are an infrequent but serious problem not only due to the physical risk they pose to the patient, but also the resulting degradation of trust in medical services and the economic damage invited by the medical facility. Medical institutions seek to prevent these incidents by taking counts of surgical items before and after surgery and checking radiographs of the patient taken after surgery. Despite these measures, patients are still at risk of objects being left inside the body due to miscounting of surgical items, objects being overlooked on postoperative radiographs, and a variety of other reasons. Thus, Shimadzu has developed Smart DSI (Detection Support with Image processing), an AI-based software that aids the detection of retained surgical items in postoperative radiographs. This article presents an overview of Smart DSI.

2. Retained Objects

The 15th Report of the Japan Council for Quality Health Care[1)] analyzed surgical incidents involving retained objects and found that, among surgical items such as gauze, suture needles, and forceps, gauze was the most common item left inside patients. The 54th Report of the Japan Council for Quality Health Care[2)] examined medical incidents involving only gauze left inside the body and noted 57 reported incidents between January 2016 and March 2019. Radiography was performed after surgery in 43 of these 57 incidents, and in 24 of these 57 incidents, the gauze count was correct before wound closure and no gauze was discovered in postoperative radiographs. The Japan Council for Quality Health Care has identified five primary reasons why gauze was not identified in these postoperative radiographs: (1) the gauze overlapped with bone, (2) the images were small making the radiographs difficult to examine, (3) the gauze was outside the field of view of the radiographs, (4) attention had been drawn to the drainage tube in

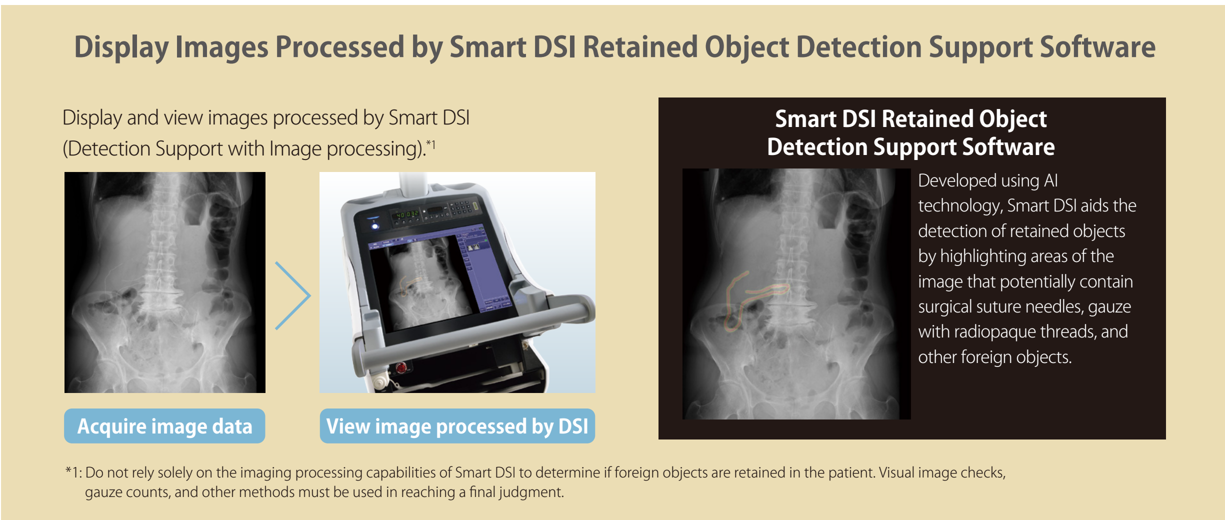

Fig.1 Fig. 1 Smart DSI Retained Object Detection Support Software

the radiograph, and (5) a number of gauze counted was the same as the expected number, leading to radiographs being checked under the assumption no gauze was present. Surgical items left inside the patient may be missed on postoperative radiographs for any of these reasons.

Smart DSI is designed to help prevent retained objects from being missed by highlighting potential surgical items in postoperative radiographs.

3. Smart DSI Retained Object Detection Support Software

Smart DSI is an image processing feature available for the MobileDaRt Evolution MX8 Version c type digital radiographic mobile X-ray system that highlights areas of radiographs that may show surgical items retained in the body.

Smart DSI performs this image processing on the mobile X-ray system and can display highlighted areas on an image around 15 seconds after acquisition of the postoperative radiograph. Fig. 2 shows the operating screen of the mobile X-ray system. Once the mobile X-ray system has acquired a postoperative radiograph, Smart DSI processes the image and displays highlighted areas in the image on the screen of the mobile X-ray system. Users can inspect images for highlighted areas on the mobile X-ray system screen and even switch between the original radiograph and the processed image. Image processing can also be performed by selecting the Smart DSI image processing button on the operating screen. Whether the postoperative radiograph is automatically sent to Smart DSI or processing must be applied manually depends on the acquisition protocol used by the mobile X-ray system.

4. Smart DSI Features

Smart DSI uses a deep learning model developed with deep neural networks. The deep learning model takes an input image, extracts features from the image that differ from anatomical structures seen in training data, and outputs the extracted information as highlighted areas that potentially correspond with retained objects. The data used to train the model was also enriched through augmentation to better account for variability in patient thickness and the different exposure conditions used by the mobile X-ray system.

Fig. 3 and Fig. 4 show radiographs processed by Smart DSI with highlighted areas indicating potential retained objects. Fig. 3 shows a frontal chest radiograph acquired by the mobile X-ray system and the processed image with a highlighted area. Fig. 4 shows a frontal abdominal radiograph acquired by

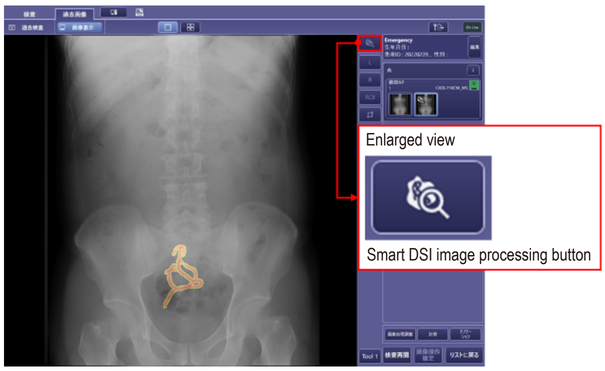

Fig.2 Mobile X-Ray System Operating Screen

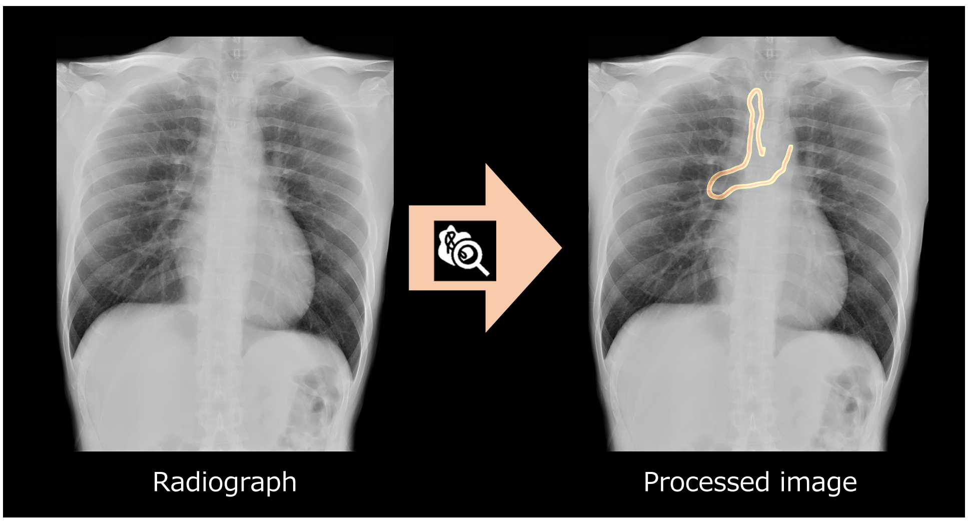

Fig.3 Chest Radiograph and Image Processed by Smart DSI

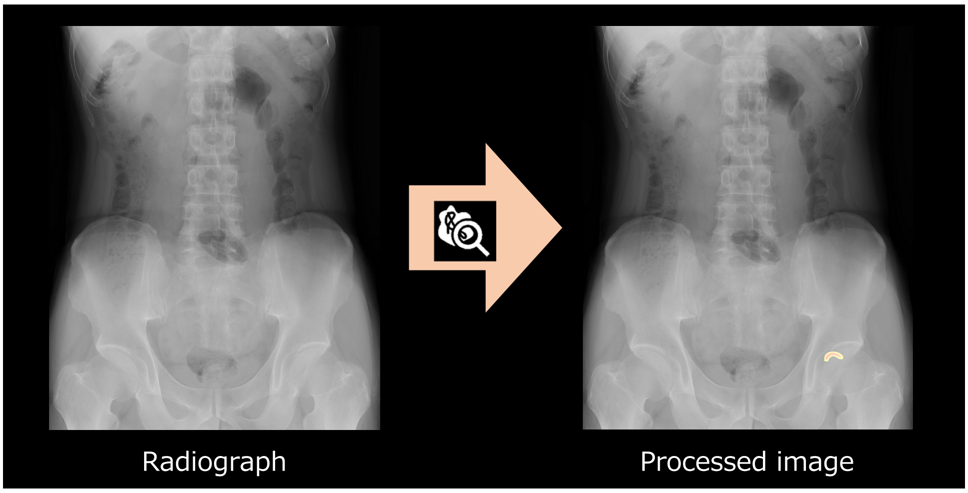

Fig.4 Abdominal Radiograph and Image Processed by Smart DSI

the mobile X-ray system and the processed image with a highlighted area. Thus, Smart DSI aids in the postoperative visual check for retained surgical items by highlighting parts of the radiograph that potentially show a retained object.

5. Conclusion

This article presents Smart DSI, an AI solution that uses deep learning to aid the identification of retained objects in the body, which is now available for the MobileDaRt Evolution MX8 Version c type digital radiographic mobile X-ray system. Shimadzu will continue to develop applications that add value to diagnostic imaging and integrate with mobile X-ray systems. Shimadzu would also like to strive to integrate customer feedback into product development for improved medical safety and more efficient workflows.

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Note: The AI (artificial intelligence) technology used in Smart DSI is not a self-guided iterative learning-type AI.

Minimally Invasive Procedures in Practice

—Further Evolution of SCORE™ PRO Advance—

Medical Systems Division, Shimadzu Corporation

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Since its release in 2015, the SCORE PRO Advance image processing engine employed in the Trinias™ angiography systems. In a recent trend to pursue minimally invasive procedures, Shimadzu updated the image processing engine to meet customer expectations for manufacturers to achieve even higher image quality and lower exposure dose levels.

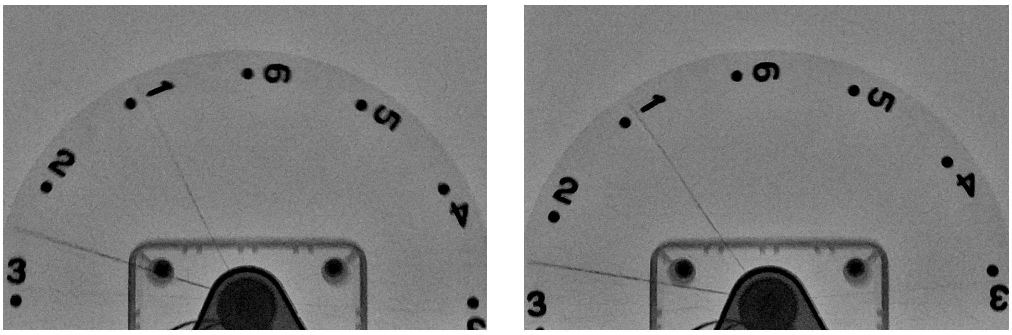
1 SCORE PRO Advance Features

In fluoroscopy, SCORE PRO Advance identifies catheters, guide wires, and other linear structures in the body by extracting their pattern and using matching technology among different image frames to reduce only random noise patterns without causing contrast deterioration or afterimage from structure movement.

For radiography, noting that linear structures in images are typically blood vessels filled with contrast media, visibility can be improved by enhancing only blood vessels and devices in images without enhancing dotted noise.

2 Description of Improvements

2.1 Conventionally, the X-ray pulse width for fluoroscopy was 8 to 13 msec (which varied depending on the X-ray parameters specified based on the object thickness). That could result in blurring if the device moved too much during X-ray exposure, which could cause decreased visibility of the guide wire tip or other features. To solve that problem, X-ray parameter settings were optimized and the pulse width was shortened to within 5 to 10 msec. The shorter pulse width decreases blurring caused by movement and provides more stable contrast between structures in different frames **(Fig. 1)**.

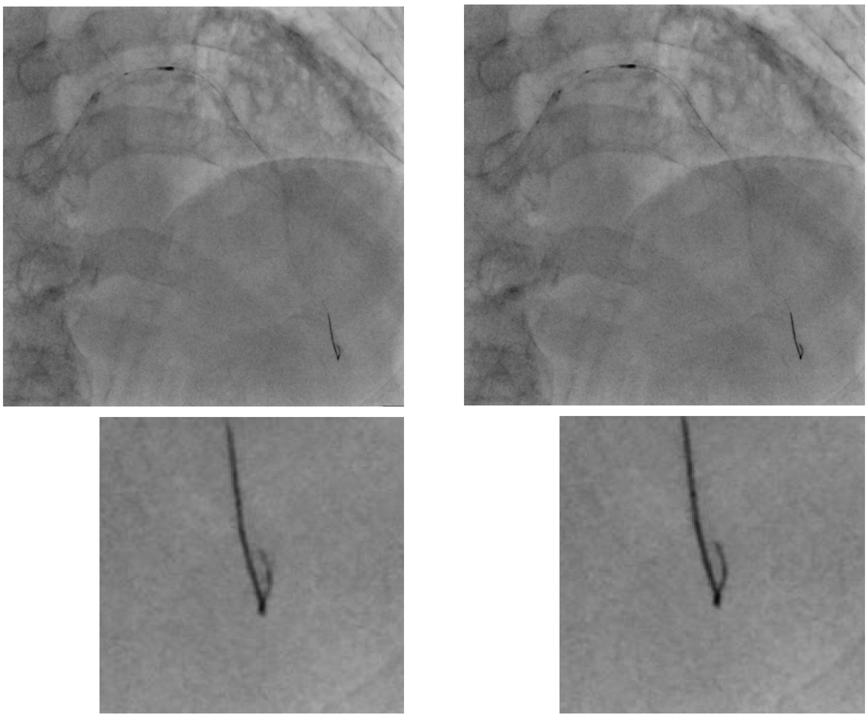


Before improvement   After improvement

Fig. 1 Blurring due to movement was further reduced after improvements

2.2 The accuracy of matching linear structures in the body during fluoroscopy was improved to further reduce afterimage of devices and other moving objects. In addition, improvements to background graininess increased the contrast-to-noise ratio (CNR) by about 10 %* in Low mode.

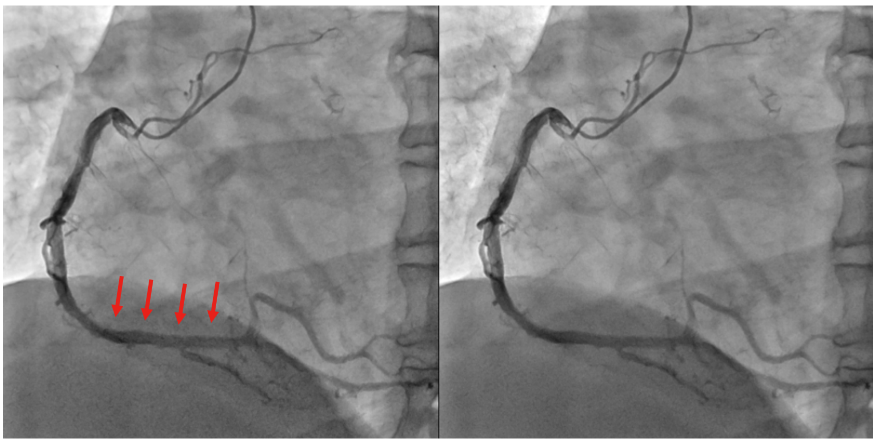
2.3 For fluoroscopy, in addition to an overall improvement in image quality, such as improved visibility and image sharpness of guide wire tips or catheter tips before injecting contrast media, which previously were sometimes difficult to see **(Fig. 2)**, an entrance dose rate for a 20 cm acrylic phantom was reduced by about 10 % * at the patient entrance reference point which had been defined as "IVR point".



Before improvement After improvement

Fig. 2 Improved guide wire visibility

2.4 For radiography as well, increased matching accuracy and background graininess improvements similar to fluoroscopy reduced noise and improved blood vessel visibility without changing exposure dose levels. The improvements were especially effective for blood vessels overlapped by the spine, diaphragm, or other objects in thicker parts of the body **(Fig. 3)**.



Before improvement After improvement

Fig. 3 Noise reduction also improved the visibility of blood vessels obscured by the diaphragm

3 Final Comments

Finally, we express our deep appreciation to all the physicians, radiological technologists, and other hospital personnel that helped with development. We will continue our research and development work in the future as well in an effort to contribute to minimally invasive procedures.

* This comparison is with our previous models.

The *hanten* coat and large and small wrapping cloths all have vibrant, prominent colors. Dyed cloth is then cut and sewn in house.

Shirushizome — Mark Dyeing

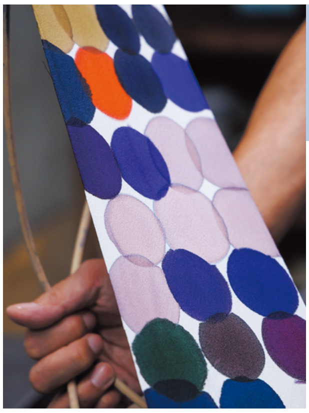
The lettering and crests are clearly visible from far away. As its name implies in Japanese, *shirushizome*, meaning mark dyeing, is a method used to emphasize marks on various cloth items such as the curtains hanging above entranceways at temples and shrines, banners, and shop curtains. It also refers to actual dyed items themselves. Legend has it that *shirushizome* has existed since the Muromachi period (1336 – 1573), and it is likely that banners bearing family crests carried into battle were made using this method. Although this type of dyeing is not much different than methods used for kimono and Western clothing, it is used to dye a large section of cloth in a single color, making it difficult to obtain uniform coloring. The concept of color is also different. Rather than achieving a harmonious color, it is more important to ensure that the colors, including background colors, make lettering and marks prominent and recognizable at a glance.

Some of the main *shirushizome* methods are *nassen* and *hikizome*. With *nassen*, a single sheet of pattern paper is needed for each color, and three sheets for three colors, so shapes are cut out to dye each section. Each pattern is placed on a mesh frame (silkscreen), laid on top of the cloth, and then a mixture of starch and dye known as colored starch is spread out evenly on the cloth with a flat panel called a squeegee. This process is repeated for the required number of colors, layering the dye.

Dye is a living thing

On the other hand, with *hikizome*, masking is required to leave certain sections white while dyeing other areas. When masking using a form, a paper pattern for starch must be made in advance for the design.

Once the design is complete, it is time to make the colors. Dye is used differently according to the materials, however, even when preparing the same dyes, the color differs day to day depending on the season, humidity, water temperature, etc., making it difficult to create the exact color one has in mind. This is the reason behind the ancient saying “dye is a living thing.” When the colors have been mixed, the cloth is pulled tight with thin bamboo strips known as tenters, and starch is placed on the sections the craftsman wants to keep white. After the starch is dry, liquid made from glue plant is worked into the cloth (this process is called “*jiire*”). This process is important in preventing color bleeding and for keeping colors uniform. Once the cloth is completely dry, a brush is dipped in dye which is then used

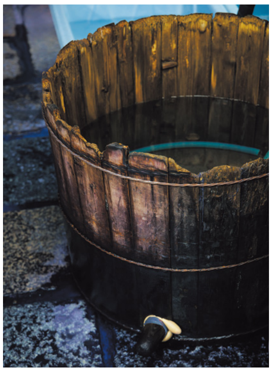


The dye is boiled, applied to the cloth, then steamed to check the coloring. This process is repeated until the desired color is achieved.

The brush is swiftly and lightly moved to quickly dye the cloth.

Once the color is applied, the cloth is hung up high and dried. The tips of Sugishita tenters have hooks which are designed so as not to harm the cloth.

The company launched their *Shirushizome* Sugishita brand to create textures on an inkjet printer like that of hand dyeing.



This wooden tub is used to wash silk. Well water that maintains a nearly constant temperature year-round is used.

Brushes for each color hang on the wall.

to apply dye to the material. Uniform colors are not the result of taking one's time, rather, they are achieved by moving the brush and spreading the dye while keeping an eye on both the amount of dye on the brush and in the cloth. If this step is skillfully executed, uniform coloring is achieved. Once the dye is applied, the cloth is steamed to fix the colors. Excess dye and starch are rinsed out with different water temperatures, the water is drained, and then the cloth is dried in the shade.

Connecting Ideas with *Shirushizome*

Eiji Sugishita, the third-generation proprietor of Kyoto Shirushizome Workshop Sugishita is adept at creating colors pulled from the ideas of customers. Sugishita says that "dyeing is chemistry." The reason is that dye produces a chemical reaction in the fibers to dye the cloth. He continues, "I dissolve baking soda into the dye, keeping it at a temperature of 60 to 80 degrees, then check it with a pH meter. I use the strong alkali to develop colors (increase the hue) and adjust them." Colors applied with a brush or squeegee are different than fixed colors once washed. The miracle of anticipating the resulting color is something only an artisan can do.

Up to the previous generation of dyers, Sugishita *shirushizome* jobs mainly consisted of large and small wrapping cloths with household crests. As times changed and fewer people gave such gifts at betrothal and wedding ceremonies, their dyeing jobs switched mainly to *hanten* coats, banners, and shop curtains, etc. Paper patterns and designs are now created digitally, and highly precise patterns are made using an automated cutting plotter. They also use inkjet printers to faithfully reproduce hand-dyed designs. Their skills are highly praised in Japan and abroad, and the Tokyo National Museum has ordered a replica of a kimono by Ogata Korin, and the Paris Collection asked them to dye items for the collection. In the fusion of digital and analog is where Sugishita's unique textures and color sensibilities lie. "Dyeing connects ideas. I look forward to continuing communicating this concept." The incredible talents of these dyers will remain as bright as their creations now and into the future.

(Special thanks to Kyoto Shirushizome Workshop Sugishita)
https://shirushizome.co.jp/

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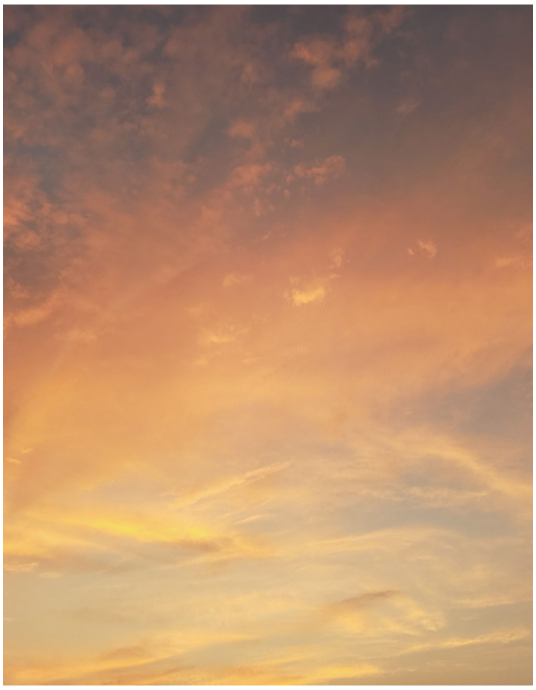

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