Application of Computed Radiography System for Horses
II. Superimposed and Subtracted Image Processings

Hiroyuki Masumitsu and Eiichi Shibata

One of the digital radiography system, the Computed Radiography (CR) system (Fuji Computed Radiography CR-201®, Fuji Photo Film Co., Ltd. Tokyo) using photostimulable phosphor has been newly developed in Japan. In this study, we estimated how two functions among several image processing function in this equipment, the superimposed and subtracted image-processing functions, were useful on X-ray diagnosis in equine veterinary practice. And then, we studied the usefulness of the superimposed image-processing function on diagnosis by using a high potential X-ray tube and of the subtracted image-processing function in elective angiography with intra-arterial injections. As a result, it was found that superimposed image-processing function was effective enough for reducing the X-ray dose, or for photography under the conditions of low X-ray tube voltage and short exposure time. By using this function, we could avoid an unclear image caused by the horse’s movement by shortening the exposure time and the amount of scattering X-ray dose was also decreased by lowering the X-ray tube voltage. In addition, it was found that, by using the subtracted image-processing function, diagnostic value of angiogram could be improved and lower concentration of contrast medium could be used.

**Key words:** horse, computed radiography, X-ray diagnosis, superimposing, subtraction.

Recently, on the development of electronic engineering and computer technology, X-ray diagnosis has seen some drastic changes. Regular X-ray image information (analogue information) can be digitalized now. Many kinds of digital radiography systems have been developed and used1-2). Among them, the Computed Radiography (CR) system using photostimulable phosphor has been developed in Japan3). In the CR system, a plate, so-called Imaging Plate (IP), made by photostimulable phosphor which stores X-ray energy, is used instead of the conventional screen/film system. X-ray image information that is recorded onto IP is read as electric signals by an image reader and is digitalized. The digital signals are then sent to an image processor and computerized, and printed onto film by an image recorder3).

In previous study4), it was found that the CR system can reduce the amount of X-ray dose and improve quality of X-ray image by trying out a plain film radiography. The CR system has many image-processing features. Among them, the function of superimposed image-processing and subtracted image-processing are very useful for diagnosis by detail informations which have not been obtained by the conventional X-ray systems3).

Superimposed image-processing enables us to process several IPs and collect image information altogether to process one image (Fig. 1). By using this function,
X-ray images, having much more information, can be obtained. A maximum of 3 IPs can be used in the current CR System.

Subtracted image-processing possesses two ways of temporal subtraction and energy subtraction. In temporal subtraction, the subtracted image is made by the subtraction between the image before the contrast medium was injected (mask image) and the image after the contrast medium was injected (live image) (Fig. 2). It extracts the image of a necessary contrast vessel for diagnosis by removing the bones and other organs.

This report describes the effectiveness of the superimposed image-processing function on diagnosis by using a high potential X-ray tube and of the subtracted image-processing function in elective angiography with intra-arterial injections.

**Materials and Methods**

1. Analysis of the Superimosed Image-processing Function

*Experimental animals:* One thoroughbred horse, male, 2 years old, body weight of 460 kg, was used in this experiment.
Equipment: Computed Radiography System (Fuji Computed Radiography CR-201®, Fuji Photo Film Co., Ltd., Tokyo), high potential X-ray tube (MS-30®, Hitachi Medical Corp., Tokyo) and Lisholm-Blende (MS X-ray Grid® [grid-ratio 10:1], Konica Medical Corp., Tokyo) were used in this experiment.

Methods: We compared images taken from one IP and three IPs for lateral oblique radiography of the shoulder joint and ventro-dorsal radiography of the hip joint in the standing position under the same condition. Shoulder joint was taken under the condition of 80-100 kVp, 40–250 mAs, FFD 120 cm and hip joint was that of 100–120 kVp, 250–800 mAs, FFD 120 cm.

2. Analysis of Subtracted Image-processing Function

Experimental animals: One thoroughbred horse, male, 6 years old, body weight of 540 kg, was used in this experiment.

Equipment: Computed Radiography System and portable X-ray tube (TP-20HR®, Tanaka Roentgen Corp, Japan) were used in this experiment.

Contrast medium: Amidotrizoic acid (Angiografin®, Sheering AG, West Germany) was used in this experiment. The medium was diluted and used at 100%, 40%, 20%, 10% and 4% concentration.

Methods: Contrast medium was injected from artery of the metatarsal dorsalis III under the condition of general anesthesia in lateral lying position. X-ray images were taken for arterial digitalis. Live and mask images were treated under the subtracted-image-processing, and the images of only blood vessels were obtained. The subtracted image was compared with the live image. The conditions were 70 kVp, 1.2 mAs, FFD 70 cm, with one IP.

Results

1. Superimposed Image-processing Function

Fig. 3 shows an X-ray image of the shoulder joint under the condition of 100 kVp, 160 mAs, FFD 120 cm. The image on the left was taken by one IP; the image on the right was taken by superimposed image-processing. As seen in this case, when an X-ray was sufficiently exposed and a good image was obtained by even one IP, much differences which influenced on diagnosis were not observed between both images even though a superimposed image was somewhat superior due to improvement of the granularity.

Fig. 4 shows the image of the shoulder joint under the condition of 80 kVp, 80 mAs, FFD 120 cm. In this case, the quality of the image became worse with only one IP due to degradation of the granularity while the superimposed image gave a satisfactory image.

Fig. 5 shows the image of the hip joint under the condition of 110 kVp, 450 mAs, FFD 120 cm. The superimposed image was better than the image processed by one IP, but the difference did not have much influence on the diagnostic value. These two X-ray photos in Fig. 5 were taken at an exposure time of 0.5 sec; the sharpness of the image was slightly lost due to the horse’s movements during the X-ray.

Fig. 6 shows the image of the hip joint under the condition of 105 kVp, 275 mAs, FFD 120 cm, at an exposure time of 0.25 sec. By shortening the exposure time, the movement of the horse did not influence the quality of the X-ray image so much, and both these images in Fig. 6 were
Fig. 3. X-ray images of shoulder joint
Remarks: Under the conditions of 100 kVp, 160 mAs, FFD 120 cm.

Fig. 4. X-ray images of shoulder joint
Remarks: Under the conditions of 80 kVp, 80 mAs, FFD 120 cm.
Fig. 5. X-ray images of hip joint
Remarks: Under the conditions of 110 kVp, 450 mAs, FFD 120 cm.

Fig. 6. X-ray images of hip joint
Remarks: Under the conditions of 105 kVp, 275 mAs, FFD 120 cm.
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Table 1. Comparison of images taken between by one IP and by three IPs

**Shoulder Joint**

<table>
<thead>
<tr>
<th></th>
<th>160</th>
<th>80</th>
<th>40</th>
<th>250</th>
<th>160</th>
<th>80</th>
<th>250</th>
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<tbody>
<tr>
<td>kVp mAs sec.</td>
<td>1.16</td>
<td>.08</td>
<td>.04</td>
<td>.25</td>
<td>.16</td>
<td>.08</td>
<td>.25</td>
<td>.16</td>
<td>.08</td>
</tr>
<tr>
<td>One IP</td>
<td>⊙</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td>×</td>
</tr>
<tr>
<td>Three IPs</td>
<td>⊙</td>
<td>⊙</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td>△</td>
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**Hip Joint**

<table>
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<tr>
<th></th>
<th>700</th>
<th>120</th>
<th>288</th>
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<tr>
<td>kVp mAs sec.</td>
<td>1.0</td>
<td>.50</td>
<td>.32</td>
<td>1.0</td>
<td>.50</td>
<td>.25</td>
<td>1.0</td>
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<td>.25</td>
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<tr>
<td>One IP</td>
<td>△</td>
<td>⊙</td>
<td>△</td>
<td>⊙</td>
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<td>⊙</td>
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<td>Three IPs</td>
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Remarks: ⊙: Satisfactory image.
△: Satisfactory image even though the image was slightly inferior in quality.
×: Unsatisfactory image.

Fig. 7. X-ray images by using a 100% contrast medium
Fig. 8. X-ray images by using a 40% contrast medium

Fig. 9. X-ray images by using a 20% contrast medium
better than the images in Fig. 5. While the image by one IP was slightly inferior in quality, the image by superimposed processing was as sharp as the image by the large quantity X-ray dose.

Table 1 shows the overall results. With an exposure time of 1.0 sec, both images made from one IP and three IPs were unsatisfactory because of loss of the sharpness due to the horse’s movements during the X-ray exposure. As seen in this table, however, it was clarified that, by using the superimposed image-processing, the quality of X-ray image was improved and the exposure time could be shorter and X-ray tube voltage could be lower.

2. Subtracted Image Processing Function

Fig. 7 shows both a live and a subtracted images by using non-concentration of contrast medium. Diagnosis could of course be done by using a live image, but a subtracted image could give a sharper image of blood and peripheral vessels, which were hidden behind bones.

Fig. 8 shows both a live and a subtracted images by using a 40% concentration of the contrast medium. Compared with the time when non-concentration of the contrast medium was used, a live image gave worse informations of vessels while a subtracted image gave satisfactory informations of the vessels.

Fig. 9 shows both a live and a subtracted images by using a 20% contrast medium. In this condition, the peripheral vessels could be seen in the subtracted image, while only the large vessels were recognized in the live image. This subtracted image was better than the live image obtained with a 40% contrast medium.

Using a 10 and a 4% contrast medium, even though the diagnostic value was not so great, a subtraction image gave an image of large vessels and some of the medium to small-sized vessels, while live image could not distinguish the vessels.

Table 2 shows the summary of the results. These result presented that, by using subtracted image-processing, diagnostic value of angiogram was improved and lower concentration of the contrast medium could be used.

Discussion

In X-ray diagnosis of racehoses, there are two diagnostic methods by kinds of X-ray tubes, that is, diagnosis by a portable X-ray tube and by a high potential X-ray tube. The former is mainly used for diagnosis of bones and arthro-diseases of the legs, and the latter is for diagnosis of bones and arthro-diseases of the trunkus (shoulders, chest, lumbus and clunes, etc.) and lung diseases. In diagnosis by using

<table>
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<th>Table 2. Comparison between a live image and subtracted image</th>
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<tr>
<td>L</td>
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<td>S</td>
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</table>

Remarks:

C : Concentration of the contrast medium.
L : Live image.
S : Subtracted image.
○ : Excellent image.
▲ : An image that could barely give diagnosis even though peripheral vessels were observed unsatisfactorily.
△ : An image without a diagnostic value, with a slight possibility of distinguishing some vessels.
× : An image which could not give any distinction of vessels.
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a portable X-ray tube, the image quality is satisfactory and X-ray dose only has to be decreased keeping the same image quality. In diagnosis by using a high potential X-ray tube, however, several problems still remained concerning improvement of image quality.

The image quality is lowered due to the scattering beam caused by high X-ray tube voltage\(^5,6\) and the long exposure time\(^5,6\). Therefore, we have been trying to remove the scattering beam mechanically together with low voltage, high current and shorter exposure time. We have also been trying to make equipment and techniques improvements.

In this study, we found that the superimposed image-processing function could give a good image even under the condition of a low X-ray dosage. We could avoid an unclear image caused by the horse’s movements by shortening the exposure time. The amount of scattering X-ray dose was also decreased by lowering the X-ray tube voltage.

Angiograms of racehorses were mostly obtained by elective angiography with intra-arterial injections, but it was not easy to find a proper spot for injection and to obtain angiogram with high diagnostic values. That is why angiograms have not been so widely used in equine veterinary practice.

Subtracted image-processing of the CR system, however, showed that even with a 20% contrast medium, it would be possible to obtain angiograms with satisfactory diagnostic values. We did not use any special equipment such as a cassette automatic changer for the angiography in this study. We only used the simplest form of subtracted image-processing function of the CR System. These findings implied that, by improving our technique, it might be able to have angiograms with satisfactory diagnostic values using even a 10 or a 4% contrast medium.

We will keep on studying to develop non-elective angiography by intravenous injection supposed to have higher potential for clinical application for equine veterinary practice.

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Literature Cited

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要約

Computed Radiography System のウマのX線診断上の有用性 II。画像の重ね合わせおよびサブトラクション処理機能について：益満宏行1、柴田栄一2（1）日本中央競馬会栗東トレーニングセンター、2日本中央競馬会美浦トレーニングセンター）---Digital radiography system の一種である輝光性蛍光体を用いたComputed Radiography（CR）system（Fuji Computed Radiography CR-201®, 富士写真フィルム㈱）が我が国において新規開発された。今回、われわれは、本装置が備えている様々な画像処理機能の中の、画像の重ね合わせ処理（多重撮影）およびサブトラクション機能の競走馬のX線診断上の有用性を評価した。すなわち、大型X線診断における多重撮影機能および動脈性の選択的血管造影診断におけるサブトラクション機能の効用について検討した。その結果、多重撮影機能は、馬の体幹部の撮影時の撮影線量の低減（低圧、短露出時間撮影）および画質の向上に有効であることが判明した。すなわち、露出時間の短縮により、撮影時の馬体の動きに起因する画像のブレを防ぐことができ、さらに、低圧撮影により散乱線の発生を少なくすることができた。また、サブトラクション機能は、血管造影診断時の診断能の向上および造影剤濃度の低減に有効であることが判明した。