ROENTGENOLOGIC DIAGNOSIS OF THE BRAIN BY RETOUCHING ROENTGENOGRAMS WITH SPECIAL REFERENCE TO THE SUBTRACTION AND HARMONIZATION

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Roentgenologic diagnosis should be made accurately by a method which casts the least burden upon patients psychologically, physically and economically. For this reason, it is necessary to collect as much diagnostic information as possible method for collecting more diagnostic information.

RETOUCHING OF ROENTGENOGRAMS

Table 1 shows a retouching method for roentgenograms.

Table 1
Retouching of roentgenograms for the purpose of Increasing diagnostic information

1) Diapositive method
2) LogEtronography
3) Subtraction
4) Color subtraction
5) Additive method
6) Color additive roentgenogram
7) Harmonization (Auto-subtraction)
Fig. 1 Television x-ray film viewer.
(1) TV camera (Vidicon)
(2) Zoom lens (f=22.5—90.0 mm, F=1:15)
(3) Illuminating box (2 section)
(4) Control panel
(5) Monochrome TV monitor
(6) Camera holder (Poraloid camera)
(7) Color TV monitor

Fig. 2 Block diagram of Television x-ray film viewer.
RETOUCHING METHOD OF CEREBRAL ANGIOGRAM

LogEtronography, 2) of Table 1, requires special instruments. However, other retouching methods are performed according to the photographic technique or electronic (video) method.

The authors have developed a television x-ray film viewer, as shown in Fig. 1, and have been performing retouching of roentgenograms according to the electronic method. Its block diagram is shown in Fig. 2, and diapositive method, subtraction, color subtraction, additive method, color additive method and harmonization can be performed by pushing buttons.

The present report deals with the investigation of the subtraction, additive method and harmonization which we have recently performed on cerebral angiograms.

1. Subtraction of Roentgenograms

The method of subtraction of roentgenograms was first reported by Ziedses des Plantes in 1937. In this method, when a diapositive is made out of one of the two films, a plain roentgenogram and a contrast roentgenogram, taken of the same site under the same projection and the two are laid one upon another for printing, the common part is subtracted and the areas which are not common are emphasized for observation. For example, in cerebral angiograms, bone shadows which interfere with reading are subtracted and the vascular images hidden behind the bones are observed well. Hanafee applied this for angiography of the cerebro-cervical region. It has been used since then for abdominal and renal angiograms also. The electronic subtraction by the use of a TV camera has been reported by Holman, Wise and Wallman. Fig. 3 presents a case of multiple aneurysms with a comparison between the original roentgenogram and the copy of electronic subtraction in internal carotid angiography. Table 2 summarizes effective roentgenograms of subtraction. For scintigrams, when subtraction is performed on the two photo-scintigrams, taken by the use of two kinds of radio-

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1) Subtraction of two plain roentgenograms taken at different times (observation of the course)
2) Angiographic films, videotape recorder etc
   (cerebral angiogram, angiocardiogram, bronchial angiogram, abdominal angiogram and vertebral venogram etc.)
3) Subtraction of scintigram
   (pancreas-scintigram (binuclear) and brain-scintigram etc.)
isotopes, for example, liver-scintigram by 198-Au. and Pancreas-scintigram by 75-Se.-methionine, it is useful in the diagnosis of pancreas since the shadow of the liver is subtracted.

2. Additive Method by Laying One Film on Top of the Other

The two films which are laid one upon another can be read on the illuminator also.

However, since it is difficult to observe them on the illuminator, observation becomes easier if a diapositive is made from one of them before laying one on top of the other. Fig. 4 (a) and (b), show the arterial phase and the venous phase of the cerebral angiograms laid one upon another. This patient has arteriovenous angioma and the last venous phase (Fig. 4-b) affords the information that the parietal vein has become narrow in the area of angioma, accompanied by a decrease in the number. Fig. 5 show a ventriculogram and a vertebral angiogram laid one upon another.

Table 3 summarizes effective roentgenograms for the additive method.

Table 3
Effective roentgenograms for the additive method

| 1) Addition of the two plain roentgenograms taken at different times |
| 2) Addition of angiograms (addition of arterial phase and venous phase in cerebral angiogram and abdominal angiogram) |
| 3) Addition of an angiogram and another contrast roentgenogram or a scintigram in the same organ |

These additive methods allow observation of the movement of blood circulation from the contrast films in angiography. Also, by laying various films one upon another, improvement of the diagnostic faculty by new reading methods of roentgenograms can be expected.

3. Color Additive Roentgenogram and Color Subtraction

Color addition of roentgenograms and chromatoroentgenography were reported by Donovan in 1951, followed by Takahashi. There are two methods in the color addition of roentgenograms: one is to print monochro-roentgenograms on color prints for coloration and development, and the other is to perform direct roentgenography on colored x-ray films for colored development. In addition, there a method to colorize the contrast of roentgenograms (Fisher et al),
that to obtain different colors according to the quality of roentgen rays (Prins et al\textsuperscript{14}) and that to distinguish the density of roentgenograms by color television (Shinozaki\textsuperscript{15}). The color monitor is used for the method in which TV camera is used. A color filter is used in front of the camera in one type of this method (Osterkamp\textsuperscript{13}). In our method, using an electronic gun of three primary colors, red, green and blue, color of the difference in the density of the monochro-roentgenogram is developed on the color monitor.

The principle of the method of color subtraction is quite the same as that of the subtraction of monochro-roentgenograms. For example, when one film is colored red and the other, green and are laid one upon the other, the common image turns yellow and the parts which are not common leave the original color.

Color addition of roentgenograms is used for observation of the objective indication (differences of color contrast) of the site of pathological changes. It is applied also for the additive method of the film, contrast roentgenogram and scintigram.

4. Harmonization of Roentgenograms

The method of harmonization makes a shadow on the x-ray imagine (effect of edge). For this retouching method, there are photographic technical method (Oldendorf\textsuperscript{10,11,12}) and TV method (Groh et al\textsuperscript{3}, Miller et al\textsuperscript{9}, Zieler et al\textsuperscript{21}). In Japan, Kawahara\textsuperscript{8} has reported on the harmonization by photographic technique and the TV method was first reported by Tanaka\textsuperscript{17}. In the photographic technique, the original film is slightly enlarged and printed on the film. This printed film and the original film are laid one upon the other for printing once more.

The property of photoelectric conversion of video camera is utilized in the method of using a TV camera. As presented in Fig. 6, one roentgenogram is taken with Camera(2) (video output (a)). When this (a) is sent to Camera(1), it is converted photoelectrically (video output (b)). When these (a) and (b) are treated with the mixing amplifier and are displayed on the monitor surface, harmonization output results. Fig. 7 is the actual copies of a test chart, and Fig. 8 shows the monitor picture of normal and harmonization signal are compared.

Fig. 9 describes a comparison among the original film, subtraction and harmonization in a cerebral angiogram. Fig. 10 shows a case of arteriovenous angioma where subtraction and harmonization are compared. As known through Fig. 9 and 10, subtraction allows a better observation of the part hidden by bone shadows and harmonization is more excellent for observation of thin peripheral
vessels. These are enlarged in Fig. 11 for observation. Fig. 12 shows the harmonized image of the arterial phase and the venous phase of the vertebral angiogram.

Table 4 summarizes the effective roentgenograms for retouching by harmonization. The method of harmonization enhances linear shadows and so is excellent for observation of the angiogram and minute shadows in the bone trabecula in the skull. Oldendorf\textsuperscript{10} designates harmonization as auto-subtraction. Having learned that the photoelectrically converutive property of the vidicon camera exerts a mild effect of subtraction and since our method of subtraction uses only one roentgenogram, we call this auto-subtractive effect. This effect makes the bone shadow thin, which results in an effective observation of the vascular image that overlaps a bone shadow.

**Table 4**

*Effective roentgenograms for harmonization*

| 1) | Roentgenograms of the soft tissue (extremities, mamma, and cervical region) |
| 2) | Roentgenograms of the site abundant in linear shadows (maxilla, bones and joints, blood vessels, lymph vessels, bronchogram and mucosal folds of the stomach and small intestine) |
| 3) | Observation of the pathological region which overlaps bones and where bone shadows have become thinner (effect of auto-subtraction) |

**DISCUSSION**

Performed for the diagnosis of brain diseases are clinical neurological diagnosis, roentgenologic diagnosis, the diagnosis by ultrasound echography, encephalogram and radioisotopic scintigrams. The roentgenologic diagnosis includes the plain film and contrast roentgenography (ventriculography and cerebral angiography) of the skull. Diagnostic information of considerable importance could be collected from a plain roentgenogram based on the increased intracranial pressure, calcification and osseous changes.

Retouching of roentgenograms is aimed at collecting more diagnostic information obtained from them. That is to collect more accurate diagnostic information, including the localization, size and nature of pathological changes, by simple roentgenologic examination.

In cerebral angiogram, the shadows of the bilateral temporal bones and the vertebral bone frequently interfere with reading of the vascular image and
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makes reading of the distribution of the thin peripheral ophthalmic arteries in the orbit difficult. In addition, it is difficult to find tumor stain in the original film of poor contrast. The method of subtraction is highly effective in such a case.

The additive method allows estimation of the movement of blood circulation by laying the films of the arterial phase and the venous phase one upon another for reading and the addition of two films with different contrast method enables a more accurate localization.

Harmonization enhances detailed linear shadows. In particular, the thin and narrow peripheral vessels show poor contrast so that detailed pathological changes are often overlooked. The method of harmonization is effective for turning these into distinct roentgenological images. In this case, the image quality is the talking-point. However, as evident from the test chart in Fig. 7, there is no change in the image quality by harmonization. The image quality of the monochro monitor in the television x-ray film viewer (Fig. 1) is 600 line horizontally and 400 line vertically and that of the color monitor, 400 line horizontally and 350 line vertically.

As the author mentioned previously, there are two methods in retouch of photograph; photographic and TV method. Photographic methods necessitates a complicated operation and much time, however, it is superior in clearness of a retouched photograph. On the other hand, photographs can be retouched easily in the TV method, but it is rather inferior to photographic method in clearness. Especially for reservation of picture on TV monitor, resolving power of polaroid film is unsatisfactory in the present machine. Above all, polaroid color film is still unsuitable for practical use.

SUMMARY

Among the various methods of retouching of roentgenograms by the use of TV camera in the roentgenologic diagnosis of the brain, particularly, angiograms, the method of subtraction, additive method and method of harmonization were examined. It is necessary to select subtraction or harmonization according to the purpose and site of diagnosis among these retouching methods. When the information on the movement of blood circulation is needed, the additive method is applied also. These retouching methods enable collection of more diagnostic information obtained from roentgenograms.
REFERENCES

Fig. 3  Comparison of original roentgenogram and subtraction (multiple saccular aneurysms).
(a) Original roentgenogram.
(b) Subtractive image improvement.

Fig. 4  Additive method of carotid angiograms (large arteriovenous racemose angioma).
(a) Addition of the early (white) and last (black) stage of arterial phase. A markedly dilated parietal vein is the efferent vessels (arrow).
(b) Addition of the early arterial phase (white) and last venous phase (black).

Fig. 5  Additive image of pneumoventriculogram and vertebral angiogram.
Fig. 6  Block diagram of harmonization and harmonization output.

Fig. 7  Copies of test chart.  
(a) Test chart: Normal procedure.  
(b) Harmonize image improvement.

Fig. 8  Monitor picture (250 KHz squar wave).  
(a) Normal signal.  
(b) Harmonization signal.
Fig. 9  Comparison of normal procedure, subtraction and harmonization (multiple saccular aneurysms).
(a) Original roentgenogram.
(b) Subtractive image improvement.
(c) Harmonize image improvement.

Fig. 10  Comparison of subtraction and harmonization (large arteriovenous racemose angioma).
(a) Subtractive image improvement.
(b) Harmonize image improvement.
Fig. 11 Magnified image of the arteriovenous angioma.
(a) Efferent dilated parietal vein.
(b) Structure of the arteriovenous angioma.

Fig. 12 Normal vertebral angiogram (anteroposterior projection).
(a) Arterial phase.
(b) Venous phase.