A PRELIMINARY EXPERIMENT OF THE OBSERVATION OF THE HYOID BONE BY MEANS OF DIGITALLY CONTROLLED DYNAMIC RADIOGRAPHY

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In order to minimize the x-ray dose given to a subject during the cineradiographic observations of the movements of the articulatory organs, as well as to fascillitate the automatic processing of the data obtained through the observations, we have devised a new radiographic technique: "Computer Controlled Dynamic Radiography". Some characteristics of the experimental scheme and the results of preliminary experiments have been reported in some detail elsewhere.[1)]

One of our primary objectives is to observe the movements of the tongue by tracking the motion of metal pellets placed on selected positions on its surface. The present x-ray generator for the pilot studies is not appropriate for this purpose due to its comparatively low acceleration voltage. The system for the pilot studies, however, proves to be satisfactory in the resolution of images of radiopaque objects. Taking advantage of this, some preliminary experiments have been conducted in tracking the movement of the hyoid bone, as a feasible and effective example of the use of our x-ray device.

The hyoid bone is a small U-shaped bone located above the cricoid cartilage. It is connected to the larynx, the mandible, and the tongue through many muscles. It is known that the larynx as well as the hyoid bone move during the pitch control gestures,[2)] but the specific characteristics of the movements of these structures are not well known. It is also reported that the shape of the pharyngeal wall is different for the pronounciation of voiced and voiceless consonants,[3)] and the position of the hyoid bone may be relevant to this distinctive function. Similar phenomena are also found for the tense and lax vowels.[4)] The observation of the movement of the hyoid bone may contribute to a better understanding of the physiology of the laryngeal and supralaryngeal structures in relation to phonetic features.

Figure 1 shows an example of the x-ray image of the hyoid bone obtained by the overall scan of the 3 x 3 cm^2 field in the object plane. Each sample point was 1-mm apart in both the x- and y-directions and the exposure time at each sample point was 1 msec. The current in the x-ray microbeam generator was set at 0.35 mA. A pin-hole, 50 microns in diameter, was positioned at a distance of 3.5 cm from the x-ray source, and the object plane was about 35 cm from the pin-hole. In order to filter out soft x-rays, an Al sheet, 0.5 mm in thickness, was placed in front of the pin-hole. The diameter of the x-ray beam on the object plane was estimated at approximately 1 mm. *

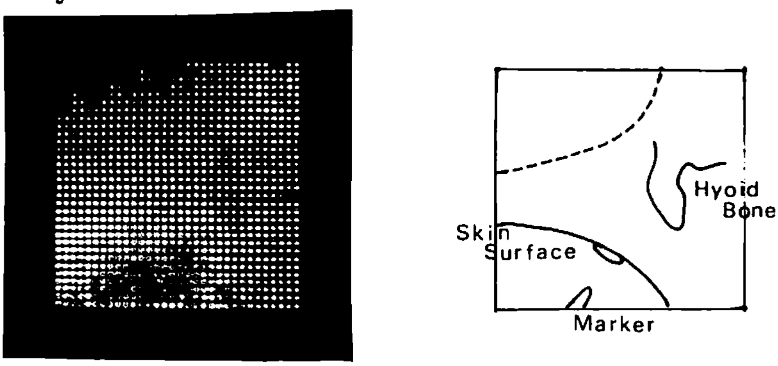

Figure 1. An example of the image of the hyoid bone.

In the lower left hand side of Figure 1, the skin surface and the metal pellet attached to it are seen. The shadow at the bottom of the picture is of the tip of the pointer that was used as a guide for positioning the neck of the subject within the image field. The cross section of the central portion of the hyoid bone appears in the middle of the right hand side of the picture. An exposure time of 1 msec per one sample point seems to be sufficient for obtaining the image of the hyoid bone with a satisfactory signal-to-noise ratio with the intensity of the x-ray microbeam presently available.

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* In the present experiment, a larger pin-hole is employed than was used in a previous experiment in order to obtain an increase in the intensity of the x-ray beam at the cost of image resolution.

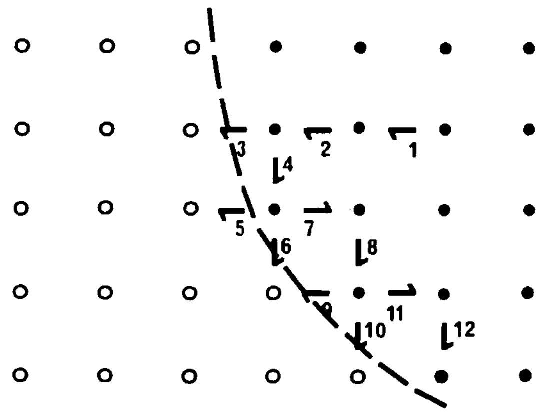


Figure 2. A basic strategy for the automatic tracing of the boundary between the darker and the brighter portion of the image.

DETECTION OF THE HYOID BONE

A tentative computer program for the automatic detection of the hyoid bone has been written and tested. The outline of the object can be traced automatically as shown in Fig. 2. By this method, x-ray exposure is given only to those sample points within a narrow strip along the boundary. Because it is difficult to give an appropriate threshold value beforehand, a set of different traces were obtained by use of tentative threshold values. Among the traces obtained, one trace that could be accepted as representing the outline of the known object was selected.

Figure 3 shows a set of such traces obtained from the data of a scanned image of the hyoid bone (the same data as shown in Figure 1). The traces are superposed on the scanned image. In this example, a trace in Figure 3 (b) will be considered to be the most appropriate one as the outline of the body of the hyoid bone.

For measuring the position of the hyoid bone, examination of the entire portion of such a trace may not be necessary. Tentatively, we used the convex shape of the inferior margin of the bone for identification of the location of the bone. Figure 4 (a) shows a trace automatically determined

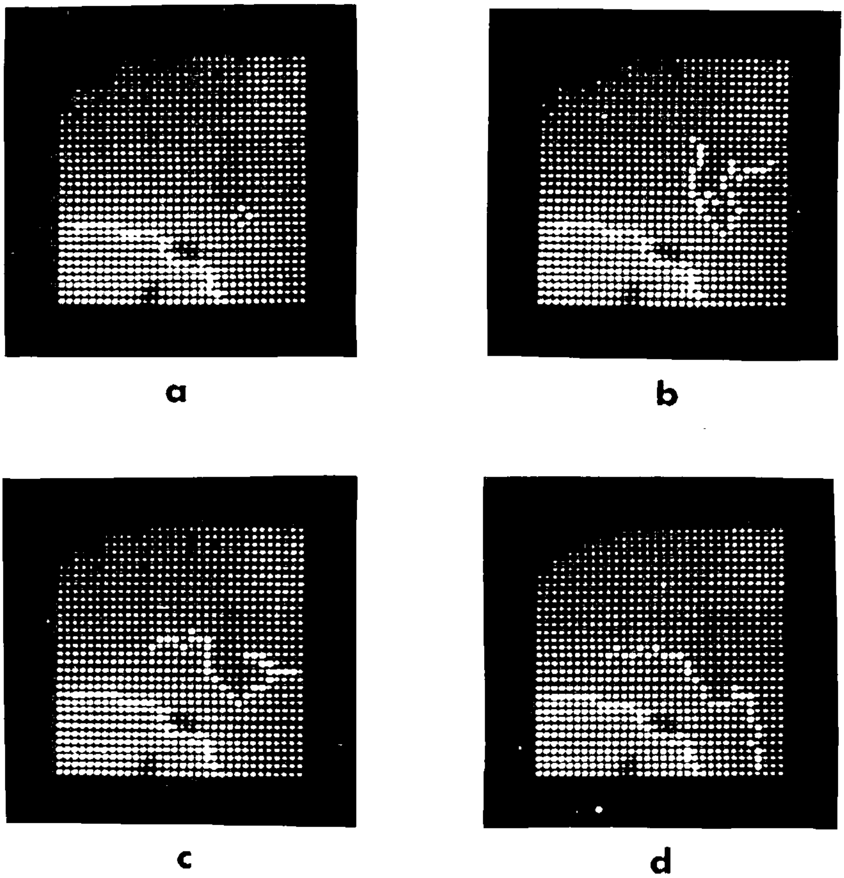


Figure 3. Superposed display of the scanned image and the traces around the body of the hyoid bone obtained with the use of different treshold values. Traces of the skin surface are also shown for reference.

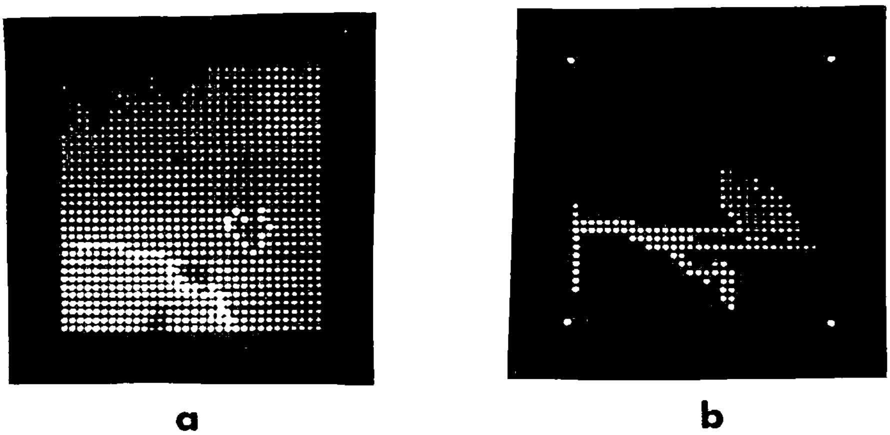
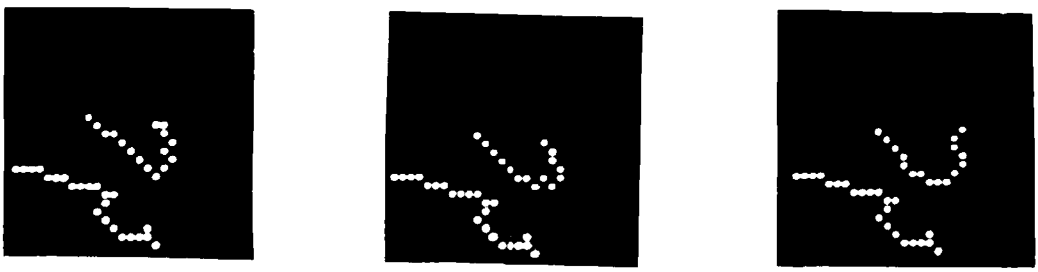


Figure 4. (a) The traces determined as the skin surface and the anterior-posterior margin of the body of the hyoid bone. (b) The sample points to be exposed during the on-line determinetion of the traces in (a).

by this principle, together with the trace of the skin surface. The sample points to be exposed in the case of on-line determinations of these traces are shown in Figure 4 (b). First, a point at the lower left corner of the image field is exposed and the threshold value for the skin surface is determined from the detected x-ray intensity in the object free area. Next, a scanning is made upward until the skin surface is encountered and then, the skin surface is traced. In order to locate the hyoid bone, scanning is made horizontally starting from a point manually selected upon visual inspection of the detected skin surface, and a sufficiently clear local minimum in the intensity pattern is judged as representing the hyoid bone. Starting from this position, tracing of the bone out-line proceeds as described above.

During the tracking of the movement of the hyoid bone, exposures for the next sample frame can be started from a point around the currently detected position of the object. In this case, the exposure of approximately 60 sample points will be sufficient for the measurement of one frame, as seen from Figure 4 (b). Examples of the traces obtained by the on-line application of the method are shown in Figure 5. The three traces were determined at successive time moments during a stationary pronunciation of the vowel [u] at a rate of approximately 10 frames per sec. There is a considerable variation in the shapes of those traces, especially with regards to the posterior portion of the hyoid-body. However, it appears that the location of the hyoid bone can be determined with sufficient accuracy from the traces of the inferior-anterior margin and its lower end.



a b c

Figure 5. The traces determined as the anterior-inferior margin of the body of the hyoid bone at successive time moments during the pronunciation of the vowel [u]. A trace of the skin surface predetermined and superimposed on these frames is also shown for reference.

A more extensive study will be required for developing the most effective method for the parctical observations of the movement of the hyoid bone.

DOSIMETRY OF THE PRESENT SYSTEM

As far as the total dose is concerned, it can be assumed that the exposure involved in the present system gives no significant radiation effects on the subject. The exposure rate on the object plane was estimated at approximately lmR/min under a uniform-scan condition of the field size of $4x4cm^2$. The measurement was performed by an ionization chamber (Model 555 Radecon with a probe 10LA, Victoreen Instrument Division) and also by a thermoluminescence dosimeter (T. L. P. Reader PNH-751 with test caps PNP-281, M. B. L. E. Co.). The settings of the x-ray generator were the same as described on page 2.

One of the advantages of the present system is that some special precautions in the computer programming will make it possible to reduce the exposure at the specific portions of the object where exposure is particularly undesirable because of high radiosensitivity. For example, in the case of the automtic tracking of the outline of a selected bone, exposure of the bone marrow can be totally avoided. More specific kinds of strategies for dose saving can be employed depending on the particular cases. In the case of the observations of the hyoid bone described above, no direct exposure is given to the mandible, the cervical vertbrae or the thyroid gland. Secondary radiation was estimated at 4mR/hr at a point 2. 5 cm apart from the x-ray beam on the object plane.

A possible radiation effect that should be considered in the present system is local damage to the skin and other tissues, because the x-ray exposure may be concentrated in a small area in such a case as tracking the movement of the specific portion of the subject. In an extreme case, for example, when the x-ray beam is constantly directed to the points within a field of $5x5\ mm^2$, the exposure rate will be approximately 60mR/min for the particular portion of the organ. Concerning the effects of such a localized exposure, no directly relevant data are available except for the cases of very large doses such as are employed in radiation therapy. However, as a tentative estimation, 30rem/year may be taken as a permissible dose for a selected portion of the skin, according to the recommendations by the I. C. R. P(1965, I. C. R. P. Publication 9). Complying with this standard, the total exposure time of 8 hours will be allowed for one subject per one year in the worst practical cases of concentrated radiation by use of the present x-ray generator.

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