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Application of single-photon emission computed tomography (SPECT) with ^{99m}Tc-MAA in evaluation of perfusion patterns during hepatic infusion chemotherapy

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In 6 patients receiving hepatic artery infusion chemotherapy for liver metastases, planar and single-photon emission computed tomography (SPECT) images of the abdomen were obtained after intravenous injection of ^{99m}Tc-phytate, and intra-catheter injection of ^{99m}Tc-MAA in the same geometrical settings. With this method, the three-dimensional intra- and extra-hepatic distribution of the agents during hepatic artery infusion chemotherapy can be evaluated.

Key words: SPECT, hepatic artery infusion chemotherapy, ^{99m}Tc-MAA

INTRODUCTION

HEPATIC ARTERY INFUSION of chemotherapeutic agents is used in many patients with multiple liver metastases. Radionuclide techniques using ^{99m}Tc macroaggregated albumin (MAA) or microsphere human albumin have been described for evaluating catheter position and organ perfusion.[1–7] However, in most of the published papers, planar imaging techniques were used and few articles on single-photon emission computed tomography (SPECT) for this purpose have been published.[8,9]

Recently we have started the application of the SPECT method in on attempt to improve accuracy in assessing tumor perfusion. With this method, intra- and extra-hepatic distribution of ^{99m}Tc-MAA can be assessed together with the liver image with ^{99m}Tc-phytate, providing better anatomical orientation. This paper reports the method and our preliminary clinical experience.

SUBJECTS AND METHODS

Six patients receiving hepatic artery infusion chemotherapy for pathologically proven liver metastases due to colorectal cancer (4 patients), rectum carcinoid (1 patient) and leiomyosarcoma (1 patient), were chosen for this study. They were 4 men and 2 women, and aged 47–73 years. All patients had an infusion port and catheter system (MICRO-PORT TOKIBO Co., Ltd.) surgically implanted. The port was placed in a subcutaneous pocket in the abdomen. Initial anterior planar and SPECT data of the abdomen were obtained about 15 min after intravenous injection of 200 MBq (5.4 mCi) of ^{99m}Tc-phytate. After completion of the initial data collection with radio-colloid, 200 MBq (5.4 mCi) of ^{99m}Tc-MAA in 5 m*l* saline was injected slowly over 5 min in the port of the perfusion device and then flushed with 5 m*l* of saline. The second SPECT and anterior planar data of the abdomen were obtained. The patient was kept in the same position throughout the studies. The same data acquisition settings described below were used in the first and second studies. A rectangular large field-of-view gamma camera (Toshiba GCA-901A) with a high-resolution collimator and a dedicated computer (Toshiba GMS-550U) were used. A 20% window centered at a 140 KeV photo peak of ^{99m}Tc was used. The anterior planar image was collected for 3 min on a 512×512 matrix with a magnification of 1.5. The SPECT data were acquired continuously for 15 min through 360 degrees at 4 degree intervals in a 64×64 matrix with

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a magnification of 1.5. Projection data were prefiltered with a Wiener filter and reconstructed with a Shepp and Logan filter. Photon attenuation was corrected by the Chang[10] technique with an attenuation coefficient of 0.07.

An anterior planar image of the abdomen with ^{99m}Tc-MAA was obtained by subtracting the initial image from the second image. The SPECT images with ^{99m}Tc-MAA were reconstructed with the projection data obtained by subtracting the initial data from the second data. Intra- and extra-hepatic distribution of ^{99m}Tc-MAA was evaluated on the anterior planar images and transaxial SPECT images.

RESULTS

There was one case with gastrointestinal ^{99m}Tc-MAA uptake, but no case with lung uptake of ^{99m}Tc-MAA was noted. In two cases, neither defects on the SPECT images with ^{99m}Tc-phytate nor localized deposits of the ^{99m}Tc-MAA on the subtraction SPECT images were demonstrated.

Images from 2 patients are shown in Figs. 1–2. In Fig. 1, multiple localized hot areas are demonstrated on the planar image, but SPECT images show distribution of ^{99m}Tc-MAA in the tumors more precisely, such as a large tumor with a doughnut pattern and smaller tumors with homogeneous up-

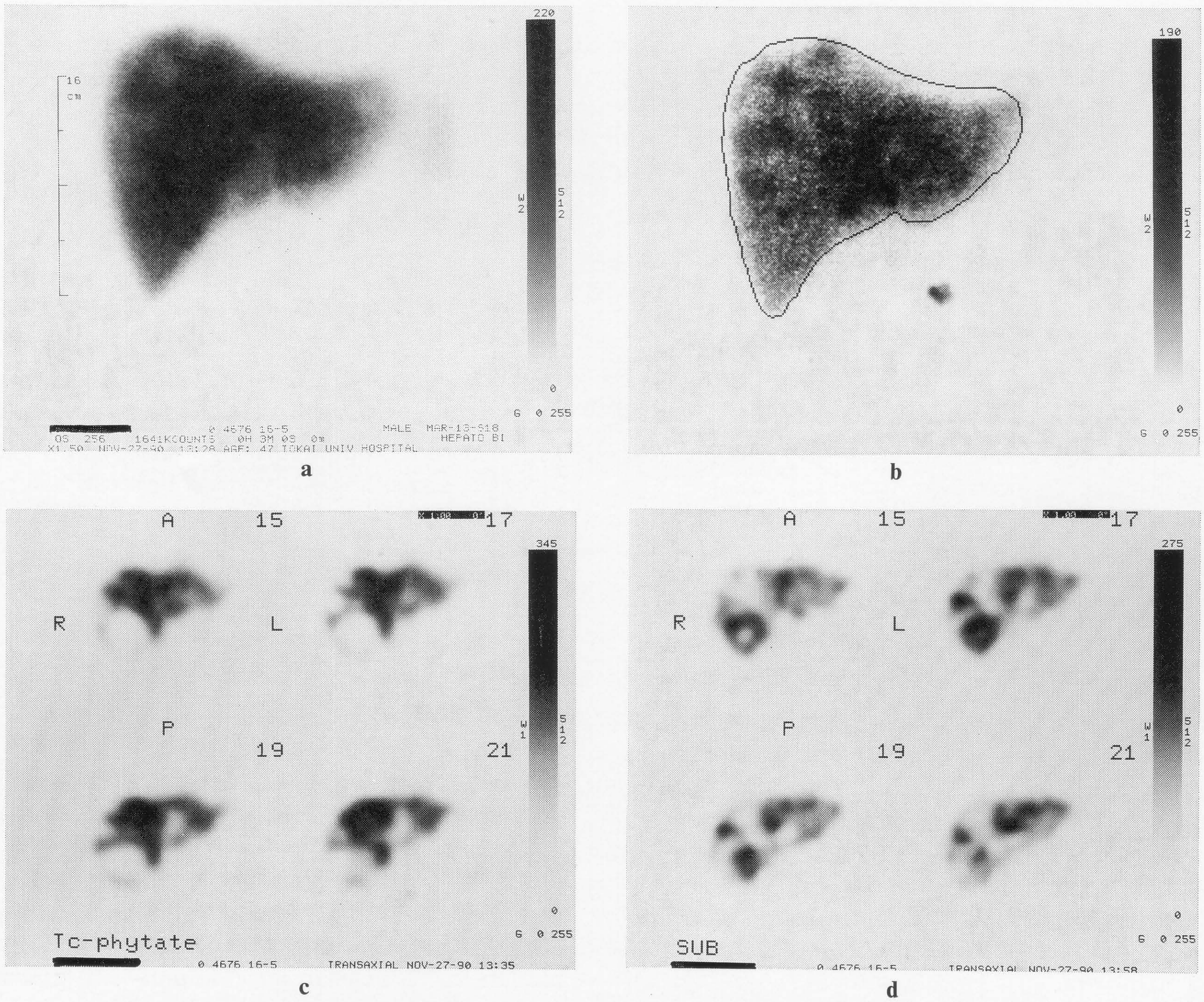

Fig. 1 47-year-old male with colon leiomyosarcoma.
a: Anterior planar image with ^{99m}Tc-phytate reveals multiple defects in both lobes of the liver. b: Subtraction planar image shows multiple localized deposits of ^{99m}Tc-MAA, corresponding to the defects on the image with ^{99m}Tc-phytate. Localized infra-hepatic hot area indicates the residual activity in the perfusion port. c: Transaxial SPECT images with ^{99m}Tc-phytate show a large defect in the lower aspect of the right lobe and smaller ones in other portions of the liver. d: Subtraction SPECT images show a large doughnut-like, and multiple smaller and homogeneous deposits of ^{99m}Tc-MAA.

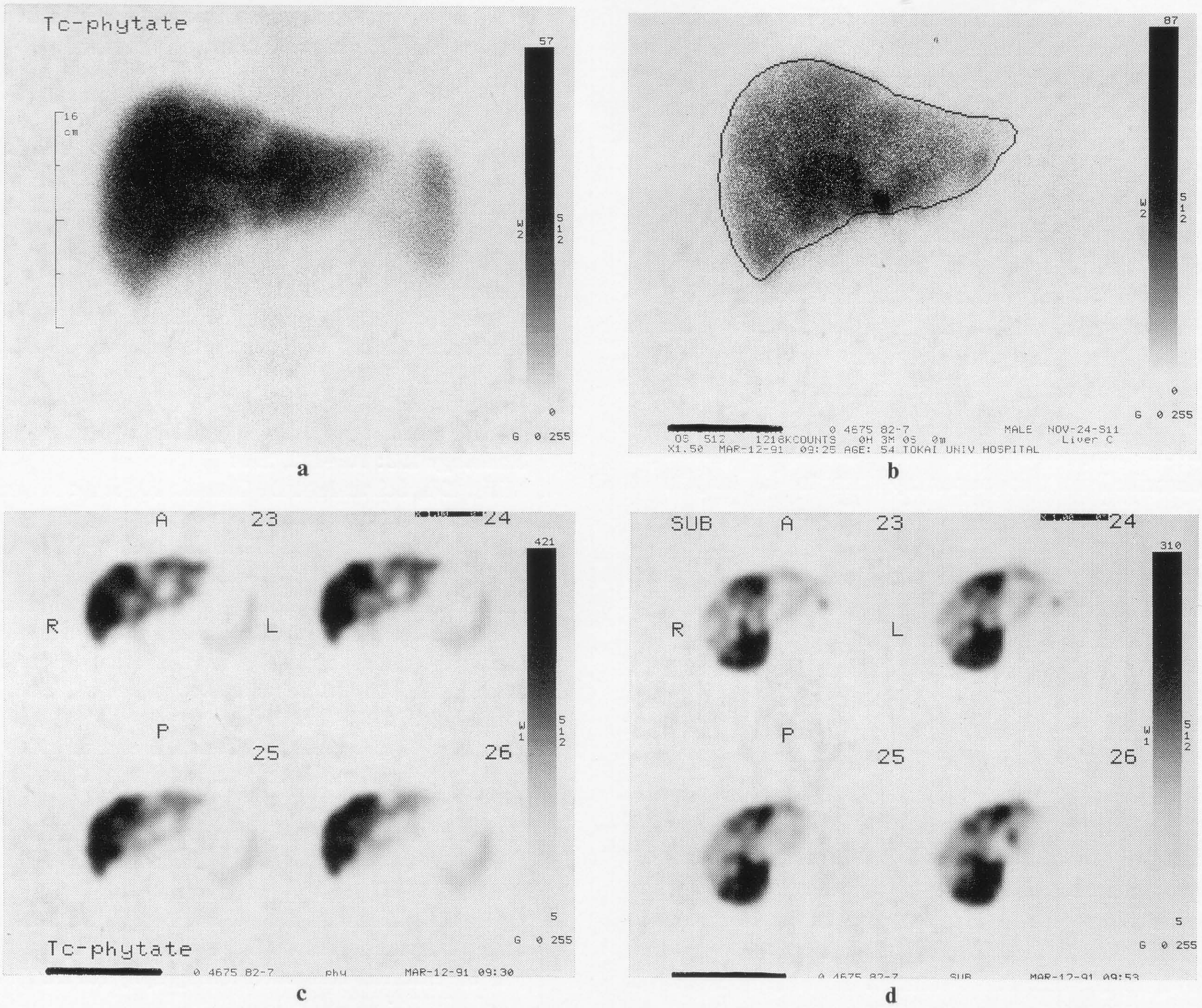

Fig. 2 54-year-old male with colon cancer.
a: Planar image with ^{99m}Tc-phytate demonstrates a focal defect in the upper aspect of the right lobe, and upper and lower aspects of the left lobe. b: Subtraction planar image shows diffuse distribution of ^{99m}Tc-MAA in the liver with an area of slightly increased uptake in the inferior-medial aspect of the right lobe. c: Transaxial SPECT images with ^{99m}Tc-phytate show a large defect in the S5 and smaller ones in S3, S4 and S8. d: Subtraction SPECT images show a large area of inhomogenous ^{99m}Tc-MAA accumulation in S5 and homogeneous hot areas in S3, S4 and S8.

take. In Fig. 2, the planar image shows only an area with diffuse and slightly increased distribution of ^{99m}Tc-MAA in the medial and lower aspect of the right lobe. However, SPECT images show multiple hot areas in the liver; a large inhomogeneous deposit in the S5 and several smaller and uniform deposits probably in the S3, S4 and S8.

DISCUSSION

Regional arterial chemotherapy of hepatic metastases has significant advantages over systemic intravenous infusion therapy, because hepatic metastases derive most of their blood supply from the hepatic artery. A critical aspect in the successful application of this therapeutic method is to keep a high target to non-target ratio of the drug during the course of the therapy. A misplaced catheter results in a change in the perfusion pattern. However, similar changing patterns may occur without a shift in the catheter position as a result of pathophysiologic mechanisms which include development of collateral circulation, arteriovenous shunting within tumors and arterial spasms.[1–3,5] ^{99m}Tc-MAA infused slowly provides a map of regional perfusion at the capillary level, which is not provided by other means. It is this level of circulation that presumably decides the therapeutic efficiency to the targeted tumors.

Extrahepatic uptake of the ^{99m}Tc-MAA in the gastrointestinal tract and lungs has been reported to be detected by the planar imaging technique.[1–7] Obtaining of the additional liver image with radio-colloid without changing the geometrical correlations and application of a subtraction technique are useful in obtaining an understanding of the precise anatomical orientations in the assessment of the extrahepatic deposit of the ^{99m}Tc-MAA. However, the evaluation of intrahepatic distribution of ^{99m}Tc-MAA by means of a planar image alone is difficult. The planar imaging does not reveal individual metastases clearly and is inadequate to define the perfusion status of individual lesions within the liver.[3,4] Application of the subtraction technique described in this paper appears to be helpful in overcoming these difficulties. The use of a radiographic contrast agent and X-ray CT has been reported,[4] but this method has not been widely used because of its limitation in the detection of extrahepatic distribution of the agent.

Previous reports have indicated that SPECT methods are useful for the evaluation of intrahepatic as well as intra-tumor distribution of ^{99m}Tc-MAA[9,10] Large nodules have a central portion that is relatively hypovascular, whereas smaller nodules are uniformly hypervascular (Fig. 1). The SPECT images with radio-colloid obtained in the same geometrical settings improve localization and size estimation of the tumors, and make it easier to grasp the relationship of perfusion in the normal liver to the metastatic tumors. This method permits a precise assessment of the intra-tumor perfusion as shown in Fig. 2. In the evaluation of chemotherapeutic agents, the status of tumor perfusion is a very important factor. Without knowledge of the perfusion status of individual metastases, the clinician cannot determine whether a poor result is due to lack of response to a particular drug or to inadequate perfusion of the tumor.

In conclusion, the SPECT method described in this paper is safe and simple. This is useful for the evaluation of hepatic tumor perfusion which is difficult to assess by a planar imaging method.

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