cuss the gastric handling of iodide. Also, since we had been working on gastric autoradiography using $^{99m}TcO_4$, we were concerned with $^{99m}TcO_4$ only. This is why the iodide part of Meier-Ruge and Fridrich's work (2) was not quoted in our communication. The gastric metabolism of iodide will be the subject of a later communication.

With regard to the cellular site of $^{99m}TcO_4$ secretion in the stomach, we have obtained further results which we would like to mention here. So far, we have used autoradiography to determine the cellular localization of $^{99m}TcO_4$ in the stomachs of mice, rats, cats, and dogs. We have found that $^{99m}TcO_4$ is predominantly handled by the mucus-secreting cells (Fig. 1): heavy grain concentration was observed at the mucus lining, and few or no grains were detected in the parietal and chief cells. These findings are in accord with those of Marsden et al. (3) and Berquist et al. (4), but they disagree with those of Meier-Ruge and Fridrich (2). Our results explain why gastric tissue in Barrett's esophagus, which lacks parietal cells, accumulates $^{99m}TcO_4$ (4) and why the gastric antrum, also devoid of parietal cells, secretes $^{99m}TcO_4$ (5).

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Resolution Limit of Positron Cameras

Two recent publications (1,2) in the Journal of Nuclear Medicine have discussed the loss of spatial resolution in positron imaging devices due to the varying range of positrons of different energies in tissue or tissue-equivalent material. While this loss of resolution is fundamental in nature and will indeed influence to a large degree the ultimate achievable resolution, particularly at high positron energies, a second equally fundamental effect, which in many camera configurations results in a more serious loss of resolution, deserves mention.

Due to the motion of the center of mass of an annihilating pair, the two back-to-back 511-keV photons formed upon annihilation are not emitted at exactly 180° with respect to each other (3). The angular spread leads to a distribution that is roughly Gaussian in shape with a full width at half maximum (FWHM) of 0.6°. This effect can be particularly significant for a system with a large detector-

to-detector separation: for a positron source midway between two detector arrays separated by 80 cm, an angular spread of 0.6° results in a distribution which has a FWHM of 4.2 mm at the detector. The resulting error in reconstructing the location of the source will depend upon the particular geometry (size of detectors, position sensitive or discrete, etc.). Nevertheless, for many systems it will contribute approximately 2 mm (FWHM) to the system resolution.

While this effect is more significant than the positron range effect for most positron-emitters, it does not seriously degrade the resolution of existing positron imaging devices which have system resolutions between 8 and 11 mm FWHM.

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Reply No. 1

Our paper on the effect of positron range on spatial resolution (1) was meant to point out the role of this single factor in the spatial resolution of positron imaging systems. For example, the line spread functions (LSFs) from the positron ranges of ^{18}F (0.633 MeV), ^{11}C (0.929 MeV), ^{68}Ga (1.90 MeV), and ^{82}Rb (3.15 MeV) have values at the full width half maximum (FWHM) and tenth maximum (FWTM) of 0.14 and 0.8 mm, 0.33 and 1.3 mm, 0.44 and 3.1 mm, and 0.61 and 5.6 mm, respectively (1,2). When these positron-range LSFs are convoluted with detector LSFs which have FWHM resolutions of 8–10 mm (FWTM of 15–18 mm), the positron-range effects are very small (1–3). However, as the inherent detector resolution is improved, the higher positron energies of ^{68}Ga and ^{82}Rb become more important. If a detector resolution of 4.0 mm FWHM and 7.3 mm FWTM is convoluted with the β^+ range LSF of ^{82}Rb, the resulting FWHM and FWTM are 4.6 mm and 9.2 mm, respectively. Thus, at a detector resolution of 4 mm FWHM, the positron ranges of some radiopharmaceuticals become appreciable, but they are still not very significant factors in image resolution.

As a result of previous discussions with Muehllehner and Buchin concerning the effect of the angular distribution of annihilation radiation on spatial resolution, we have investigated this effect (2). As Muehllehner states, the two 511-keV annihilation photons are not always emitted at 180° in a laboratory frame of reference (i.e., as opposed to the center-of-mass reference) (4). The shape of the angular distribution approximates an inverted parabola centered at 180°. The width of the distribution is a function of many variables and is particularly ambiguous for in vivo radiopharmaceuticals. Because of the heterogeneity of the body composition and the range of the β^+, the local environment in which annihilation occurs is impossible to define. Never-

theless, some estimates of the effect on resolution in an imaging system can be made by considering typical values of the width of the angular distribution. Stewart (5) measured this width for positrons annihilating in 34 different elements and found a mean FWHM of about 0.5° with a range of 0.2–0.7°.

The effect of these angular distributions, as discussed by Muehllehner, is to add additional width to the best resolution attainable with annihilation coincidence detection. This width is directly proportional to the separation distance of the pair of coincident detectors (2). If one takes 0.5° to be the mean angular distribution around 180°, then this produces a line spread distribution with a FWHM of 4.8 mm and 2.7 mm for detector separation distances of 111 cm [e.g., PETT III (6–9)] and 62 cm [e.g., Cho et al. (10)], respectively. In support of Muehllehner's conclusions, this effect is typically greater than that of β^+ range and, whereas these effects place some limits on the highest resolution possible with annihilation coincidence detection, they do not pose significant problems with the realistic system resolutions of 8–10 mm. Depending on the particular detector separation distance, system design, and radionuclides employed, the combination of positron range and angulation error will typically contribute 1–3 mm FWHM to the total system resolution. Since the several factors that affect resolution are not simply added together, but are convoluted together, a slower changing loss in resolution is obtained than the simple sum would (incorrectly) indicate.

It is important to point out that this discussion and that of Muehllehner are in reference to only two factors affecting spatial resolution. There are obviously many other factors (which are, in fact, typically more important) that determine the overall system resolution: statistics, depth-dependence and resolution of collimated detector response, sampling frequency, detection efficiency, photon attenuation, scattered radiation, random coincidence rate, object motion, display resolution, etc. All of these physical considerations must be carefully analyzed before a system can be optimally designed, since there are many trade-offs among these factors. For example, as the detector separation distance is increased, one achieves more uniform detection efficiency and resolution, better scatter coincidence rejection, and other improvements that are beyond the scope of this letter (6–12). On the other hand, this is done at the expense of an increase in the annihilation angulation errors, lower efficiency (although effective design can remove this to a major degree), and the need for more or larger detectors to cover the field of view of the object. Discussions of the above design considerations are given in Refs. 2 and 6–12.

Lastly, one must contain one's scientific enthusiasm by making some effort to include cost-effective constraints in the design.

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Reply No. 2

Dr. Muehllehner's letter "Resolution Limit of Positron Cameras" seems to be an interesting observation. Measuring the finite spread of the 180° back-to-back radiation has been a classical physics problem in the nuclear physics community. In addition to the "finite range" of the positron, the angular uncertainty deserves mention in any discussion of expected improvements in resolution in future positron cameras.

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Measurement of Unbound ^{99m}Tc in ^{99m}Tc-Labeled Human Serum Albumin

In a paper by Lamson et al. (1), a rapid method was reported for the estimation of unbound ^{99m}Tc in preparations of ^{99m}Tc-labeled human serum albumin (^{99m}Tc-HSA). Their method was based on protein precipitation using trichloroacetic acid (TCA), followed by filtration through a 0.22-μm disposable membrane filter. Their main problem was the retention of unbound reduced ^{99m}Tc on the filter membrane.

We wish to report an alternative method, namely, centrifugation, for the separation of the precipitated protein from its supernatant. The ^{99m}Tc-HSA is added to a centrifuge tube containing 0.1 ml of HSA carrier solution (7.5 mg/ml).