The analytical sensitivity of Tc99m radionuclide ‘milk’ scanning in the detection of gastro-oesophageal reflux

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Abstract. The analytical sensitivity of radionuclide ‘milk’ scans for detecting gastro-oesophageal reflux (GOR) has been assessed using an in vitro simulation test. Five factors were found to affect the ability to detect simulated reflux: isotope concentration, absolute gamma camera sensitivity, absorber thickness overlying the ‘oesophagus’ and volume and duration of reflux. We found that a critical volume-duration product must be exceeded for reflux to be detected. Radionuclide milk scanning appears to be much less sensitive in detecting transient events like GOR than might be expected from previously reported static simulation studies.

Tc99m radionuclide ‘milk’ scans are now widely used for the detection of gastro-oesophageal reflux (GOR) in infancy and childhood. The technique is simple and more sensitive than the barium swallow in the detection of GOR [1, 2]. Heyman et al. [3] have suggested, from a static simulation of the milk scan, that volumes of pulmonary aspiration as little as 0.025 ml may be detected.

During the course of our studies of GOR in infancy, a number of children vomited during the period of scanning. We were surprised to observe that a significant number of these vomits (23/67) were not associated with discernible change in oesophageal activity on the gamma camera image (Fig. 1). Ref-

Fig. 1. 1-min images acquired during episodes of vomiting. In image (a) reflux from stomach (St) is visualised only when pooled in mouth (Mo) (false negative). By contrast, in image (b) activity is clearly seen in oesophagus (O).
laxed material was registered by the gamma camera only when it pooled in the mouth.

It seemed likely that the camera failed to detect the refluxed material because the event had fallen below the limits of the gamma camera's analytical sensitivity. In the absence of published information we have performed in vitro simulation tests to establish the sensitivity of 'milk scans' in detecting GOR.

**Methods**

A plastic wash bottle fitted with an extension tube (internal diameter 0.6 cm) and filled with 200 ml solutions of Tc99m pertechnetate (concentrations 1.2, 2.3, 5.3 μCi/ml) was positioned in front of a gamma camera with a large field of view, behind various thicknesses of perspex absorber (0, 1, 2, 3, 4, 5 cm). GOR was simulated by compressing the bottle and filling the extension tube to a level of 20 cm for varying durations (1, 2, 5, 10 s).

The experiment was repeated using a fixed concentration of isotope (1.5 μCi/ml) and different extension tube diameters (0.3, 0.4, 0.6, 0.8 cm). These gave reflux volumes of 1.4, 2.5, 5.7 and 10.1 ml.

This model approximates the situation in vivo: the concentrations used are similar to those reported [1, 3] and tubing length is comparable to oesophageal length (mouth to lower oesophageal sphincter) in infants less than 6 months of age (range 16–22 cm) [4]. Since the oesophagus is a potential space, varying the diameter of tube allowed investigation of a range of reflux volumes. The amount of tissue overlying the oesophagus relative to the gamma camera also influences the ability to detect reflux. We therefore used absorber thicknesses up to 5 cm to investigate the effects of different thicknesses on oesophageal count density. Durations of reflux between 1 and 10 s were studied to simulate the rapid transit of materials through the oesophagus that would be anticipated in a vomit.

To assess the effect of absolute camera sensitivity the first experiment was performed with a low-energy all purpose collimator (NEMA sensitivity 6.0 counts/s per μCi) while in the second a high sensitivity collimator (NEMA sensitivity 10.2 counts/s per μCi) was used.

All images were acquired in a digital 64×64 pixel matrix. Quantitative analysis of the images was performed by defining a region of interest around the image of the extension tube using the computer light pen. The total number of counts within the region was divided by the size of the region (number of pixels) to yield an average extension tube counts per pixel (CPP). This was used as an index of reflux.

**Results**

The average extension tube CPP was found to be proportional to both volume and duration of reflux (Fig. 2). Similarly, increasing the radioisotope concentration of reflux or absolute gamma camera sensitivity produced a proportional increase in extension tube CPP. The presence of increasing absorber thickness between the extension tube and the gamma camera face led to an exponential fall in extension tube CPP.

Expressed mathematically:

\[ \text{ext. tube CPP} = K \cdot V \cdot t \cdot \text{conc} \cdot \text{CS} \cdot e^{-\mu x} \]  

where \( K = \) constant \((1 / \text{no of pixels in region of interest})\), \( V = \) volume of reflux \((\text{ml})\), \( t = \) duration of reflux \((\text{s})\), \( \text{conc} = \) concentration of radioisotope \((\mu \text{Ci}/\text{ml})\), \( \text{CS} = \) absolute gamma camera sensitivity \((\text{counts/s/μCi})\), \( x = \) absorber thickness \((\text{cm})\) and \( \mu = \) linear attenuation coefficient for 140 keV photons in perspex absorber \((0.11/\text{cm})\).

Empirically, for our gamma camera/computer system, it was noted that reflux was not discernible until the extension tube CPP exceeded 0.60. This figure, which could not be improved upon by computer enhancement of the image, represents a 'detection threshold' and substituting known values for \( K, \) conc, CS, \( \mu \) and \( x \) in equation 1 means that an associated volume-duration product must be exceeded for that event to be detected. Figure 2 illustrates that a concentration of 1.5 μCi/ml and absorber thickness of 0 cm this product is equal to approximately 4 ml·s. Thus, a volume of 4 ml would have to be present for at least 1 s (or a 1-ml volume for 4 s) to be detectable.

**Discussion**

While the reported sensitivity of Tc99m labelled 'milk' scans for static events such as pulmonary aspiration may be very high [3] there is no similar infor-