Regional Pulmonary Distribution of Krypton-81m Gas Delivered by Different Breathing Systems

Abul B. Mostafa, Peter O. Childs, Nigel R. Williams, and David A. Causer

Department of Physics and Nuclear Medicine, Dudley Road Hospital, Birmingham, England

Regional pulmonary distribution of ^{81m}Kr gas delivered by three breathing systems was determined. Data from 18 patients were analyzed. Posterior images were obtained using each breathing system in turn. Distribution of Kr gas was determined in terms of penetration and zonal indices. For penetration indices each lung was divided into a central, intermediate, and peripheral region and these indices, defined as the ratio of counts/cell in the intermediate or the peripheral region over those in the central region, were calculated. For the zonal indices each lung was divided equally into upper and lower zones and the percentage ratio of the counts in each zone to the total counts in both lungs was calculated. For all patients, in addition, the size, height, and width of each lung were determined from computer images. These parameters were compared between the breathing systems using a paired t-test. It was found that there were no statistical differences among the three breathing systems, either in the regional pulmonary distribution of the ^{81m}Kr gas or in the overall shapes of the lungs.

J Nucl Med 26: 191–193, 1985

In one of our earlier publications (*1*) we reported on the efficiency of different krypton-81m (^{81m}Kr) gas breathing systems used for pulmonary ventilation studies. Four breathing systems were described: these included a reservoir system, an oxygen face mask, a nasal cannula with soft sponge and another nasal cannula without sponge. Each system delivered ^{81m}Kr gas to patients with a different efficiency. The reservoir system delivered gas more efficiently than did the others. Recently, Hastings et al. (*2*) used similar breathing systems for determination of regional pulmonary ventilation with ^{81m}Kr gas. They reported that different breathing systems produced different ^{81m}Kr gas distribution within the lungs and that the lung size, measured from apex to base, varied significantly. This difference was ascribed to changes in breathing pattern resulting from varying internal resistance between systems.

We have reanalyzed the data of 18 patients from our original group of 30 patients. Only these patients inhaled ^{81m}Kr gas delivered through three breathing systems: a reservoir system, a face mask, and one type of nasal cannula with soft sponge. Each patient provided three posterior lung images produced by inhaling ^{81m}Kr gas through each of the three systems in turn. There was a delay of approximately 3 min between the use of each breathing system. In all but three patients the sequence of reservoir system, face mask, and nasal cannula was used. In one patient the sequence was reservoir, nasal cannula, face mask, while in the other two the breathing order was face mask, nasal cannula, reservoir. Posterior images of 100k counts were made and stored by a computer in a 64 × 64 matrix.

ANALYSIS OF THE DATA

Lung images from the three breathing systems were simultaneously displayed on a color television screen. The background was gradually subtracted until the two lung fields of each image were just separated. Each lung was then divided as illustrated in Fig. 1A and B. An isocount contour, equal in magnitude to the background cutoff, was applied to the extremities of the lung fields. Horizontal (x-axis) and vertical (y-axis) coordinates of the extremities of each lung were determined. For the determination of penetration indices, each lung was divided into three regions of interest (ROI) in a way similar, but not identical, to that described by Pavia et al. (*3*) (Fig. 1A). The ROIs were referred to as central, intermediate, and peripheral. The central ROI occupied one quarter of the width, and the middle third of the height, of each lung. The intermediate ROI occupied the area bounded by an isocount contour 20% above the background cutoff. (For example, if the

Received Jan. 30, 1984; revision accepted Sept. 12, 1984.

For reprints contact: Dr. A B Mostafa, Dept. of Physics and Nuclear Medicine, Dudley Road Hospital, Dudley Rd., Birmingham B18 7QH, England.

TABLE 1
Comparison of Penetration Indices Among Three Breathing Systems
(Mean and s.d.)

Item	Breathing systems		
	Reservoir	Face mask	Nasal cannula
LI*	1.26 (0.21)	1.25 (0.18)	1.27 (0.22)
LP†	0.59 (0.12)	0.59 (0.11)	0.61 (0.14)
RI‡	1.38 (0.18)	1.42 (0.23)	1.42 (0.17)
RP§	0.61 (0.11)	0.63 (0.13)	0.63 (0.10)

* LI = left intermediate ROI.
† LP = left peripheral ROI.
‡ RI = right intermediate ROI.
§ RP = right peripheral ROI.

TABLE 2
Comparison of Zonal Indices Among Three Breathing Systems
(Mean and s.d.)

Item	Breathing systems		
	Reservoir	Face mask	Nasal cannula
LU*	22.0 (2.6)	21.9 (2.4)	21.4 (2.5)
LL†	25.6 (4.5)	25.4 (5.4)	25.8 (5.5)
RU‡	23.7 (2.5)	23.7 (3.0)	23.4 (3.1)
RL§	28.6 (5.8)	28.8 (5.6)	29.4 (6.0)

* LU = left upper zone.
† LL = left lower zone.
‡ RU = right upper zone.
§ RL = right lower zone.

background cutoff was 15%, the intermediate ROI was drawn on isocount contour of 35%.) The peripheral ROI lay between the extremities of the lung defined by the background cutoff and the intermediate ROI. To determine the zonal indices, each lung was divided equally into upper and lower zones (Fig. 1B). Note that a separate ROI was delineated for each image whether or not it occupied the same position as another in the field of view. This removed any ambiguity as to whether an ROI defined on a particular image fitted another truly or not.

The counts from each ROI and the total number of pixels over each lung field were obtained for all images. In addition, the height and the width of each lung were determined. The height was measured at the midpoint of the maximum width, and the width at the midpoint of the maximum height. To find the distribution of ^{81m}Kr gas in the different regions of the lungs, penetration indices (PI) for the intermediate and the peripheral ROIs were calculated as follows:

$$PI_{int.} = \frac{\text{counts/pixel in intermediate ROI}}{\text{counts/pixel in central ROI}}$$

$$PI_{per.} = \frac{\text{counts/pixel in peripheral ROI}}{\text{counts/pixel in central ROI}}$$

Zonal indices were calculated by taking the ratio (as percentage) of counts in each zone to the total counts in both lungs. The indices for the left and right lungs were calculated separately. The penetration and zonal indices, area, height, and the width of each lung were compared between the three breathing systems using a paired t-test.

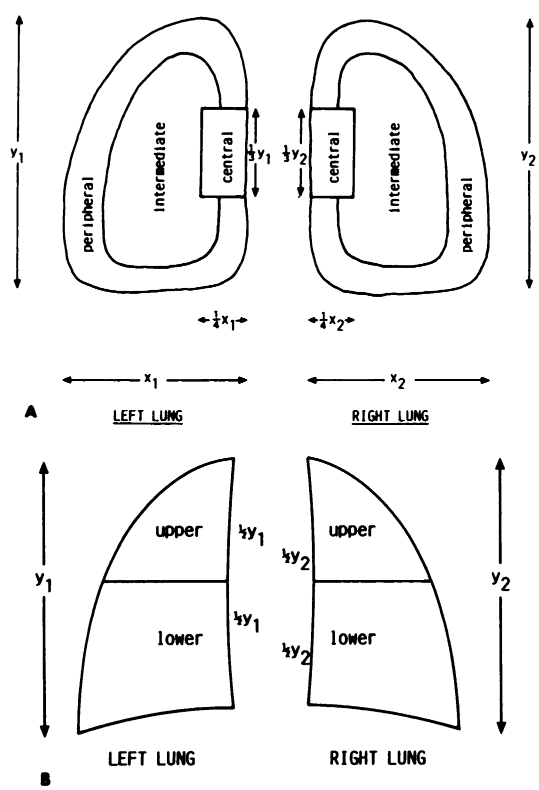

FIGURE 1
Delineation of ROIs on posterior lung image. For penetration indices, each lung is divided into central, intermediate, and peripheral ROIs (A). Central ROI occupies one quarter of width and middle third of height of each lung. Intermediate ROI is drawn with isocount contour 20% above background cutoff. Peripheral ROI lies between extremities of lung defined by background cutoff and intermediate ROI. For zonal indices each lung is divided equally into upper and lower zones (B)

TABLE 3
Comparison of Lung Area, Height, and Width Between Three Breathing Systems
(Mean Values in Pixels, with s.d.)

	Item	Breathing systems		
		Reservoir	Face mask	Nasal cannula
Area	LL*	327 (98)	326 (86)	322 (87)
	RL†	347 (90)	353 (91)	349 (88)
Height	LL	25.0 (3.1)	25.0 (3.4)	24.8 (3.6)
	RL	25.6 (3.2)	25.6 (3.2)	25.3 (3.3)
Width	LL	13.4 (2.4)	13.7 (2.3)	13.7 (2.2)‡
	RL	13.8 (2.4)	14.0 (2.7)	14.0 (2.5)

‡ Compared with reservoir system, paired t = 2.557, $p < 0.05$.
* LL = left lung.
† RL = right lung.

RESULTS AND DISCUSSION

The summary of the results is in Tables 1, 2, and 3. Tables 1 and 2 show the regional distribution of ^{81m}Kr gas in the two lungs, in terms of penetration and zonal indices, among three breathing systems. Comparison of each lung in terms of area, height, and width is shown in Table 3. Each table gives mean and standard deviation values, which show a wide variation in the sample population. Such variation is expected because the size of the lungs and the gas distribution in them will vary from one patient to another. However, the test of significance used was the paired t-test, which compared the same parameter obtained from each patient between the breathing systems.

Tables 1 and 2 show that there is no significant difference between the penetration and zonal indices. This suggests that the regional pulmonary distribution of ^{81m}Kr gas delivered by the three breathing systems is the same. Table 3 shows that the area, height, and the width of the lungs do not change significantly for a majority of the tests. However, there is a single exception: the width of the left lung from the nasal breathing system differed significantly ($t = 2.557$, $p < 0.05$) compared with that of the reservoir system. This significant difference has occurred in only one of the 42 paired t-tests performed on the data. We think that this is a chance occurrence in a relatively small population.

Results of the present investigation differ from those of Hastings et al. (*2*) in the measurement of lung size. Their study was based on 22 patients divided into six groups each containing three to six patients. Each patient inhaled ^{81m}Kr gas through only two breathing systems. In addition, the measurement of lung size was limited to a single parameter, the height of the lung. Our investigation is based on 18 patients, each inhaling through all three breathing systems and with five different parameters: penetration and zonal indices, area, height, and width measured from each lung in all patients. On the basis of these findings we believe that our results are more meaningful.

We conclude that neither the regional pulmonary distribution of ^{81m}Kr gas nor the indicated shape of the lung differ significantly among the three breathing systems. Our previous work (*1*) showed that a reservoir system delivers more ^{81m}Kr gas to the lungs, and that images are obtained in half the time compared with other systems. A breathing system of this nature can be used without misrepresenting the shapes of the lungs or the pulmonary distribution of gas.

ACKNOWLEDGMENTS

The authors are grateful to Dr. L. K. Harding for many useful discussions.

REFERENCES

1. Mostafa AB, Childs PO, Causer DA: A quantitative evaluation of breathing systems used with ^{81m}Kr generator. *J Nucl Med* 24:157–159, 1983
2. Hastings DL, Prescott MC, Shields RA, et al: Choice of delivery system for ^{81m}Kr ventilation studies. *Nucl Med Comm 5*:414–415, 1984 (abstr)
3. Short MD, Dowsett DJ, Heaf PJD, et al: A comparison between monodisperse Tc-99m labeled aerosol particles and ^{81m}Kr for the assessment of lung function. *J Nucl Med* 20:194–200, 1979