PERFORMANCE OF A PROTOTYPE MULTI-DETECTOR WHOLE BODY COUNTER

John KALEF-EZRA*, Stratos VALAKIS

Medical Physics Laboratory, Medical School, University of Ioannina, Ioannina, Greece

**** e-mail: jkalef@cc.uoi.gr***

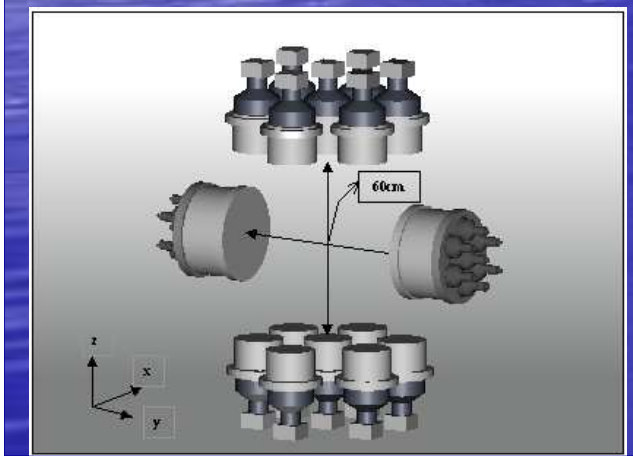
INTRODUCTION

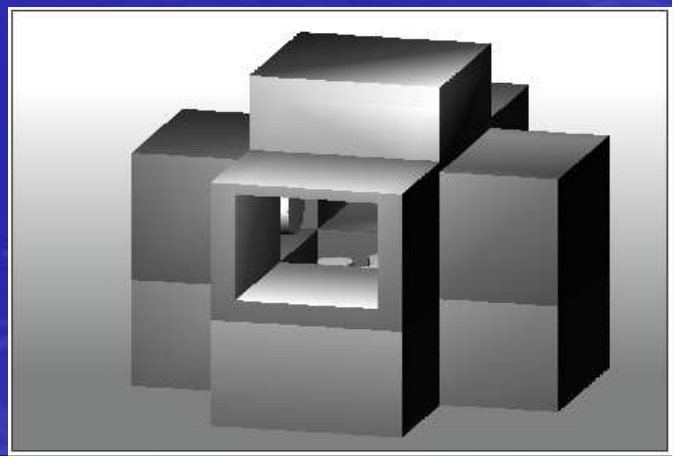
A multi-detector shadow-shield whole body counter (WBC) to be used in both radiation protection and clinical studies was designed, constructed and calibrated.

Its performance was tested carrying out 35 min-long measurements (8 scans of 2.0 m length each, with a speed of ~46 cm/min).

MATERIALS AND METHODS

The counter is equipped with sixteen cylindrical NaI(Tl) detectors located in the central region of the shielded tunnel made of 10-cm thick Pb bricks. Detectors with nominal diameter and height 15 and 5 cm, respectively, were symmetrically arranged in two arrays of seven detectors each, above and below the subject lying supine on the counter bed. In addition, two NaI(Tl) detectors (29 cm x 10 cm) were placed laterally, as well as a hpGe for high-resolution spectroscopy.





MATERIALS AND METHODS

Rectangular bottles, made of high-density polyethylene and filled with aqueous solutions, were used to assess the background signal and test the predictions of Monte Carlo simulations.

Measurement precision and accuracy, linearity with activity, and minimum detectable activity (MDA) were assessed.

RESULTS: SHORT-TERM PRECISION

- Measurements performed on a phantom of an adult man, that contained 20 kBq of ^{99m}Tc, showed a 0.9% relative precision.
- Double successive TBK measurements carried out on a phantom of an adult filled with 4.3 kBq of ^{40}K solution (139 g of K) (n=2x6) showed a short-term phantom precision, $S_{s,ph}$, of 2.62 g.
- Double successive TBK measurements with repositioning carried out on ten adult subjects with repositioning (n=2x10) exhibited a short-term *in vivo* precision, $S_{s,iv}$, of 3.0 g.

RESULTS: LONG-TERM PRECISION

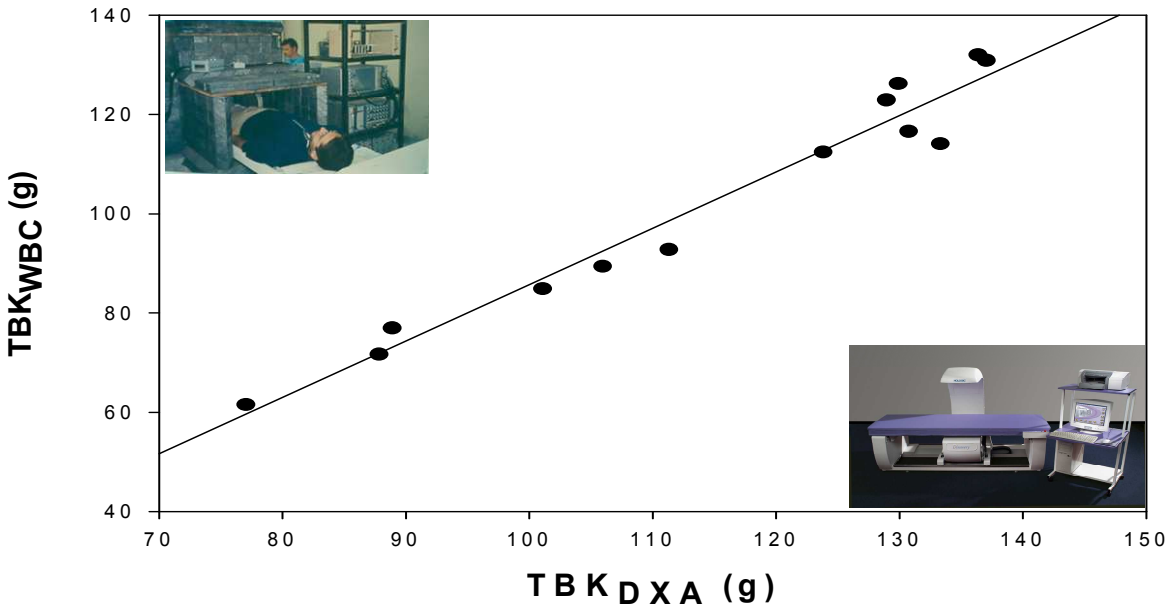
- Fourteen TBK measurements carried out over a 6-month period on a phantom containing 139 g of K showed a 3.63 g long-term precision, $S_{l,ph}$
- The *in vivo* long-term precision, $S_{l,iv}$ was 3.9 g of K (2.8%), derived by the equation:

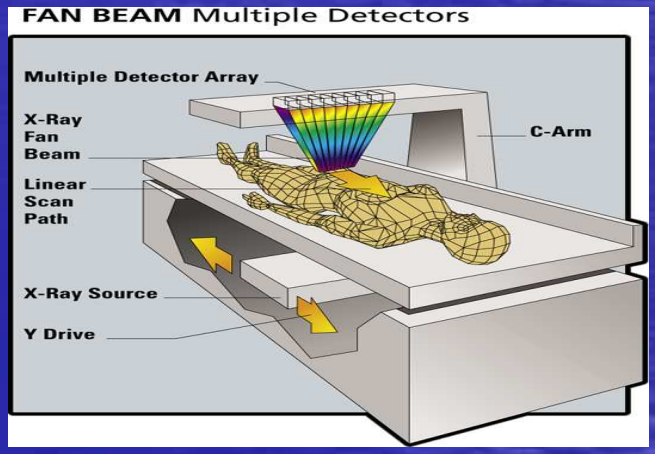
$$S_{l,iv} = (S_{s,iv}^2 + S_{l,ph}^2 - S_{s,ph}^2)^{1/2}$$

- Twenty TBK measurements performed on an worker with 136 g of K in his body during a 3 month – long period, showed a precision of 4.1 g, assuming TBK stability in the worker over the study period. This value is similar to the calculated one, 3.9 g.

RESULTS: ACCURACY

TBK assessed by whole body counting was linearly correlated (r=0.981, SEE 4.9 g) with that assessed indirectly by total body fat-free mass measurements (FFM) in 13 healthy adults, (5 male and 8 female, body mass, 50 to 113 kg, BMI 19 to 42 kg/m^2) using a Discovery W dual energy X-ray absorptiometry unit (DXA) and the sex - age dependent data on TBK to FFM ratio proposed by Kehayias et al. *

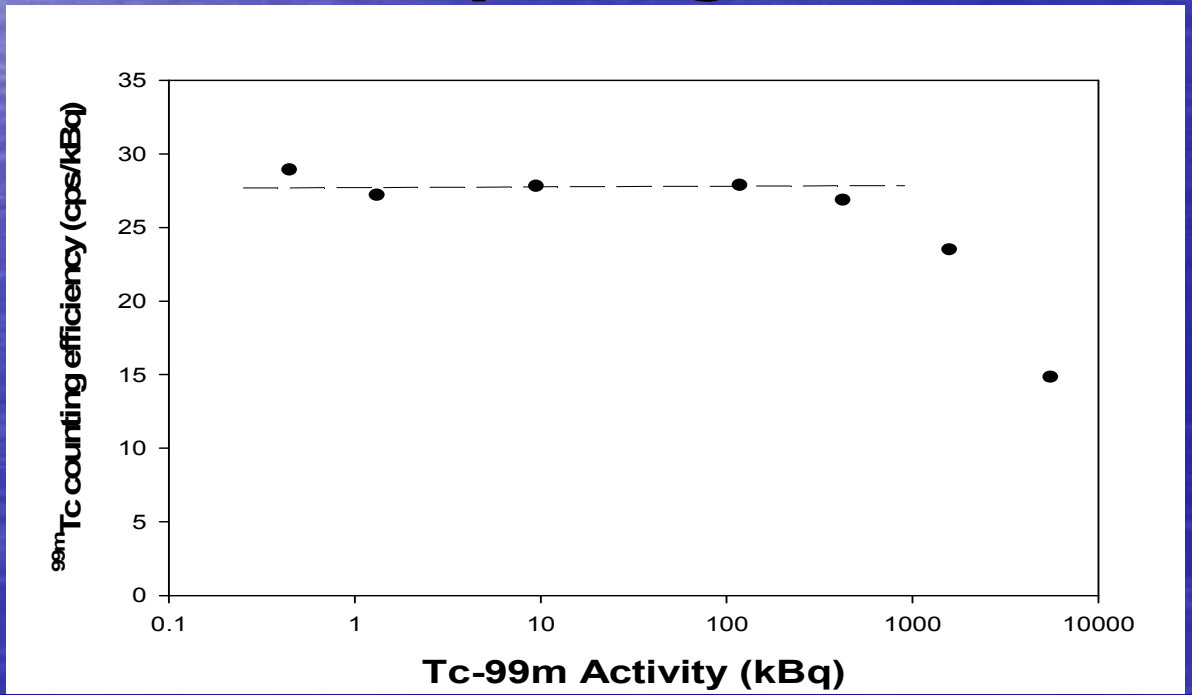




*Kehayias JK, Fiatarone MA, Zhuang H, Roubenoff R (1997) *Total body K and body fat: relevance of age.* Am J Clin Nutr 66:904-910

RESULTS: LINEARITY WITH ACTIVITY

Measurements on a 75 kg / 170 cm phantom containing 450 Bq to 5.6 MBq of ^{99m}Tc and 4.3 kBq of ^{40}K indicated adequate linearity of the ^{99m}Tc measurements up to ~300 kBq using the data on dead time provided by the used emulation software and sub-linearity at higher activities.



RESULTS: MINIMUM DETECTABLE ACTIVITY

The minimum detectable activity, MDA, in a 71 kg/ 170 cm subject was assessed using the relationship

$$MDA = [4.653\ s_b + 3] / \varepsilon\ t$$

where,

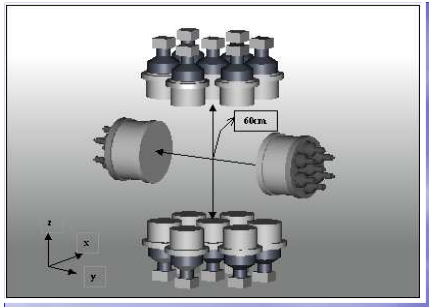
s_b is the standard deviation of the blank count,

ε the counting efficiency, and t the counting time.

Table 1: Minimum detectable activity

nuclide	^{99m}Tc	^{137}Cs	^{137}Cs*	^{40}K
energy (keV)	140	662	662	1460
MDA (Bq)	31	30	31	290

** under presence of 140 g of potassium*



DISCUSSION

A prototype shadow-shield counter equipped with 16 NaI detectors was constructed, calibrated and tested

The performance characteristics allows its use for the assessment of internal radioactivity in radiation workers and general public, human body composition studies as well as in metabolic studies.

The counting parameters can be adjusted to special features of each application. For example, t can be reduced to 4.3 min (a 2 m-long scan) in case of claustrophobic persons, emergencies and even for triage following a radiological incident.

In case that the radionuclide of interest is located in a single organ, or of infant to be counted, a steady mode can be selected, increasing the counting efficiency and decreasing MDA.