QUALITY CONTROL OF WHOLE BODY IMAGE UNIFORMITY

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Abstract--- **Whole body (WB) imaging facility is available in modern SPECT without exception and it is used in a significant proportion of patient studies in daily work. In Bulgaria, this part represents 60 to 80% of the total number of studies.**

WB scan consists of 3 phases that are performed sequentially in continuous mode without pause between them - electronic, mechanical and electronic scanning. It is essential that the camera maintain its spatial resolution and sensitivity as the camera system moves over the patient. It is generally the opinion that to ensure good WB image uniformity the electronic scan speed at the start and stop regions of a scan should be equal to the scan speed of the mechanical motion.

Quality control (QC) is one of the corner stones of nuclear medicine and an obligatory prerequisite for adequate diagnostic imaging. Two parameters determine the quality of WB image: resolution and uniformity. While QC methods have been developed to quantify the resolution the problem of quantifying WB image uniformity remains open. Therefore, the QC program requires a precise test to periodically check the constancy of scan speed during WB scan. Such a test will in fact be an assessment of the condition for achieving high quality WB image uniformity.

In this paper we present a comprehensive set of QC procedures which can be applied for acceptance testing and for regular quality control of WB image uniformity. The tests for continuous monitoring of WB scan speed are described in detail and results are presented.

Keywords--- **quality control, whole body image uniformity, whole body scan,**

I. INTRODUCTION

Whole body (WB) scan capabilities are available in contemporary SPECT gamma cameras without exception. This function constitues the majority of gamma camera applications. In Bulgaria it takes up 60 to 80% of all SPECT examinations.

The WB scan is performed by either moving the camera gantry or by moving the patient bed such that the total length of the patient passes the field of view of the detector(s). Any WB scan comprises three phases (steps), which are performed continuously with no intervals in between. The first and third phase can be referred to as electronic scanning, with the detector being still. The second phase, with the detector moving with regards to the patient can be labelled mechanical scanning.

The electronic scan speed at the start and stop regions of a scan should be equal to the scan speed of the mechanical motion. It is essential that the camera maintain its spatial resolution and sensitivity as the camera system moves over the patient. Constant sensitivity during the WB scan ensures uniform WB image. Literature on the field has so far provided no satisfactory description of the principles (algorithm) of WB scans.

WB image quality is defined by two parameters: resolution and uniformity. While resolution capability has long been merited with established methods for quantitative assessment [1], such methods pose an open topic when it comes to WB image uniformity. It is evident that WB image uniformity depends on the proper and unobstructed functioning of the scanning device.

Quality control (QC) of WB image uniformity demands a procedure for continuous monitoring of WB scan speed, which should yield appropriate data for quantitative assessment. The latter should be subject to minimal error, so as to supply objective grounds for comparison with assessments in further procedures.

Since the introduction of WB scan, it has been heavily emphasized that “the speed should be calibrated periodically” [2] as this is the foremost requirement to achieve the necessary WB image uniformity.

In internationally acclaimed guides on gamma camera QC such as National Electrical Manufacturers Association (NEMA), the problem of assessing WB image uniformity was initially raised in 1994 [1], augmented in 2001 [3] and remained unchanged until 2018 [4]. The first WB image uniformity quality control procedure [1] recommends qualitative assessment of the WB image uniformity by attaching a Co-57 sheet source to the collimator and performing a WB scan. It is expected that “visual inspection of the WB image will highlight most non-uniformities”. The grounds for adopting a qualitative assessment was the suspicion that a quantitative assessment of uniformity would be difficult to acquire with clinically relevant scan speed. NEMA later recommended a semi-quantitative approach [3], which was based on the assumption that “The perpendicular resolution, measured with line sources parallel to the direction of motion, is affected primarily by the performance and alignment of the scanning mechanism". This opinion regarding the QC of WB speed remains unchanged up to the last issue of NEMA [4].

The Co-57 sheet source method grew largely popular and was proposed by different authors in slightly altered versions. In one of them, the Co-57 sheet source is put in three different places on the patient table, then three WB scan are performed continuously [5]. The ensuing statistical processing of the collected data is expected to yield a representation of the degree of WB image uniformity.

Another method [6] has the WB scan performed on the Co-57 sheet source placed under a 4 quadrant phantom, the latter rotated 45° along the length of the detector motion. The method then prescribes a visual assessment of the WB image quality.

It is worthwhile mentioning that a principal disadvantage of Co-57 flood disk source is its high cost and limited useful life (T1/2 - 270 days). To avoid the application of a Co-57 sheet source, one author [6] proposes a WB scan of 10 point sources of equal activity arranged on the table equidistant apart. The statistical processing of the 10 captured images is used for assessment of WB image uniformity.

An additional approach was proposed [7] which included a WB scan of a single point source with a subsequent assessment of the data in the graph. A value of the point in graph that falls outside the +/- 2 average standard deviations interval is considered a malfunctioning of the scanning system. Although not explicitly stated, it is presumed that during post processing the author excludes both high intensity endpoints in the graph. A drawback of this approach is that when using a single point source the beginning and end of the WB scan are missed by the procedure.

The methods discussed so far utilize either a qualitative assessment [1], [6] or propose discrete point, instead of continuous, surveys [3], [6], [4], [5] of WB image uniformity.

The first and so far only publication that is wholly dedicated to a quantitative assessment of WB uniformity is by Blokland et al. [8]. The authors propose placing a Co-57 sheet source on top of the lower detector during the WB scan and retrieve from the WB image a longitudinal profile. The graph of the profile will be flat if WB scan speed is constant. The retrieved profile however carries a considerable statistical noise, which hampers pinpointing WB scan speed fluctuations that are small in amplitude and short in duration. This is the reason why this method cannot find practical application.

This approach was also described in other publications [9], [6], yet existing graphs as a result of its execution are only 2 [8], [9].

This otherwise clever system has two shortcomings, the latter being why so much statistical noise exists, thus significantly diminishing the utility of the method:

- Width of the profile. In majority of gamma cameras width of the profile is restricted to 5 pixels. Five pixels span only 2% of the Co-57 sheet source surface (circa 8 MBq) which results in high statistical noise.
- Scan speed. It is obligatory to apply clinically relevant scan speed – 10-12 cm/min.

A considerable advantage of the approach is that it affords a continuous monitoring of WB scan speed, thus also of WB image uniformity. To bring out the full potential of the approach the Co-57 flood disk source could be replaced by a suitable phantom to produce a profile with acceptable levels of noise, comply with clinical speed scanning requirements and generate a count rate of up to 20 kcps.

II. Materials and method

We developed phantoms and a method for quality control of WB image uniformity, which ensure little noise at clinical speed of scanning and a count rate lower than 20 kcps.

Figure 1 displays the two phantoms which are filled with colourized water and placed on the detector in their working positions. Phantom №1 is a Plexiglas box with internal dimensions 455 x 10 x 20 mm and volume nearly 90 ml. Phantom №2 is a capillary plastic tube with length 50 cm and internal diameter 1,2 mm. The tube is fixed in a strictly straight line on top of a solid base. Both phantoms are equally suitable for the purposes of this study, hence going forward one phantom is referred.

The phantom is filled with a homogenised Tc-99m solution. Activity around 200 MBq generates a count rate less than 20 kcps if LEHR collimator is used. In order to reduce personnel radiation exposure, a protective lead shielding in the form of a U section could be placed covering the phantom. The shielding

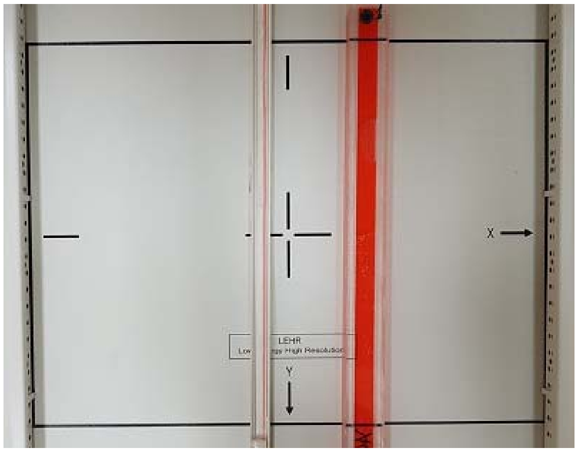

Fig. 1 The two phantoms placed on the detector 2

may be used as a container for the safe carry of the phantom.

With regards to gamma cameras with two detectors, it is advised that only detector 2 (lower detector) is switched on, while detector 1 remains switched off, in order to avoid confusion while processing the WB scan results. Users should also not forget to switch off Autocontur (Body contour) before commencing WB scan.

Pre-requisite: prior to executing a WB scan, a successful test has been carried out of the uniformity of the detector field.

1)Place the phantom on the face of the collimator in parallel with the scan direction. Check that the count rate is less than 20 000 cps.

2)Acquire a static image of 5 mln counts into matrix 256x256 and draw a profile along the phantom image. If the profile is a flat line - proceed to 5).

If the profile is not a flat line consider two issues – the phantom solution is not homogenies or the sensitivity of the detector in this direction is not uniform.

3)Rotate the phantom at 90^{o} and place it in CFOV, in parallel with the long axes of the detector.

4) Acquire a static image of 5 mln counts into matrix 256x256 and draw a profile along its length.

If the profile of the static image is not a flat line – consider refilling the phantom with homogenized solution of Tc-99m and proceed to 1) again.

If the profile of the static image is a flat line – stop the WB test and consider checking of the detector uniformity.

5)Set the scan speed to 12 cm/min and scan length to be 200 cm.

6)Acquire a WB image and draw a profile along its length.

If the profile of the WB image is a flat line – WB scan yields a uniform image.

If the profile of the WB image is not a flat line – consider service call.

There exists a speedier avenue for ascertaining the constancy of WB scan speed with two point sources:

1)Have two sources available. Each source has a volume of around 0,5 ml in a 2 ml syringe. It is recommended that the activity of one source be around 70 MBq, and of the other – around 100 MBq (LEHR collimator).

2)Place one source close to the upper (leading) edge and the other source close to the lower edge of detector field.

3)Set the scan speed to 12 cm/min and scan length to be 200 cm.

4)Acquire a WB image.

5)The WB image retrieved from each source is a line between two points with high intensity. Fig. 2. Draw a profile along each line excluding the endpoints.

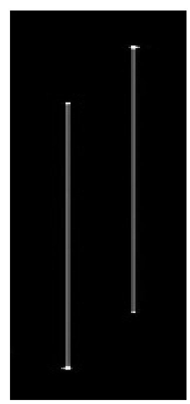

Fig. 2 WB image of two syringes placed on D2

This method is convenient for a quick check, when there is reason to suspect faulty WB scan speed. When the activity of the two point sources is different, the profiles will not overlap, which will aid visual analysis.

III. Results

Profiles of a static image of the phantom and of WB image are displayed in Fig. 3. Evidently the scanning mechanism of the tested gamma camera works perfectly as the electronic and mechanical scan speeds are visually the same.

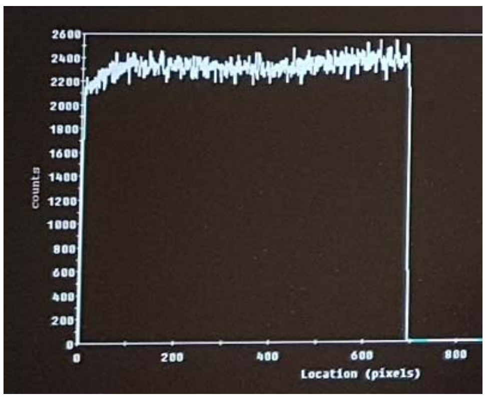

Fig. 4 Profile indicates problem of scanning mechanism.

Fig. 4 shows an illustrative example of a gamma camera where a difference exists between the electronic and mechanical scan speeds, possible due to transportation system malfunction.

Post processing in the two-syringe method is slightly different – any of the two lines of the WB image end with two points of high intensity (Fig. 2). The profile must lie between the 2 endpoints (Fig. 5 left), in order to derive reasonable graph representation (Fig. 5. Right). The green graph corresponds to the initial electronic speed of scanning and the mechanical scan speed, while the red graph displays the mechanical scan speed and the final electronic scan speed. The two profiles provide enough information to make inferences regarding equivalence between the three speeds of scanning as well as the transitions between them.

This method is practicable solely if the processing software permits to draw a profile with restricted length between 2 points. Otherwise, when the profile runs from one end of the WB image to the other, the result will resemble Fig. 6. In this case, one does not have available details of the graph of each line.

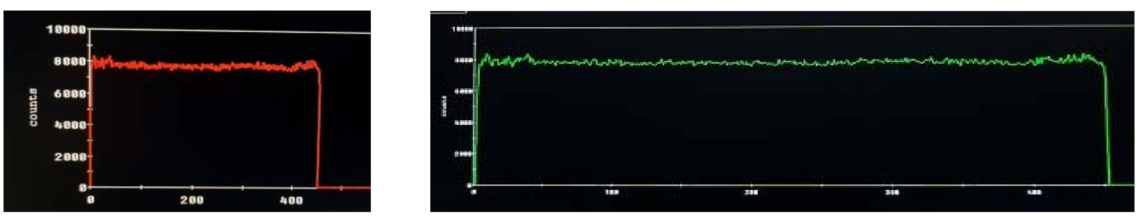

Fig. 3 Profile of the phantom (left) and profile of the WB image of the phantom (right)

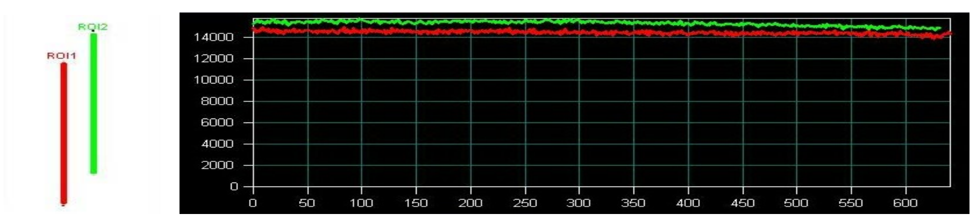

Fig. 5 Profiles span the lines without the endpoints.

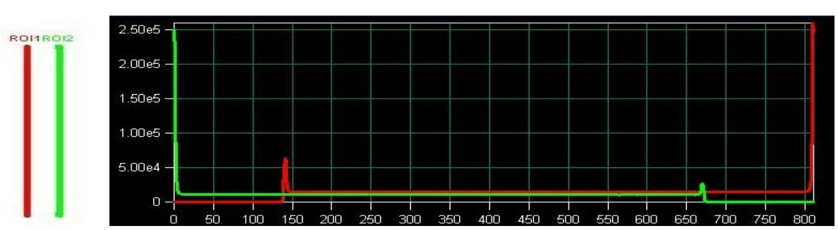

Fig. 6 Profiles span the entire length of the whole body image.

IV. Discussion

The paper has proposed a method and phantoms with the aim of testing for WB image uniformity. The submitted two phantoms are easy to make. Their construction allows uncomplicated and swift filling, which minimizes radiation exposure of staff. The relatively small volume (90 ml) of the Plexiglas phantom facilitates the in-advance homogenization of the Tc-99m solution in a 100 ml syringe. The volume of the plastic tube is around 1 ml and homogenization is not a concern.

The proposed method for QC of WB image uniformity depends on the availability of Tc-99m generator and excludes the need for the expensive and with relatively short useful life Co-57 sheet source. Activity of the phantom around 200 MBq generates count rate around 10 kcps (LEHR collimator), i.e. there is room for availing of even higher activity in order to further decrease statistical noise. This increases the sensitivity of the method in discovering comparatively small deviations of WB scan speed with low amplitude and short surges. The recommended scan speed is the clinical standard of 10-12 cm/min. The method includes obligatory verification of uniformity of the phantom, whereby it ensures objective premises for deriving reliable data.

The approach put forth enables continuous estimation of every moment of the WB scan in a graphic form that can be additionally exploited to yield meaningful data for further quantitative estimation.

The paper also advances an express method using two point sources to check the performance of WB scan when suspicion of fault arises. Even visual inspection of the two retrieved profiles lends reliable assessment as to the performance of the WB scan along the length of the entire table. This method can be further developed to yield more information by adding more point sources placed on various spots on the detector field, e.g. for continuous estimation of sensitivity during WB scan. We consider the variants with more than two sources redundant, as long as sensitivity of detector field is ensured with uniformity correction which is always switched on.

Application of the method with any of the two phantoms is relatively easy and straightforward and it is very unlikely that an error is made during performance or post processing. The two-syringe method requires more caution and expert knowledge of the properties of the profile drawing software. This method is not recommended if the software does not allow to draw a profile with a definite length but only affords an end-to-end profile of the detector field.

Final remark. When performing a QC of WB scan (unlike all other procedures) perhaps we should more closely simulate clinical conditions, viz. we ought to load the table with the weight of a normal patient – 70-100 kg. The reason for this being that some WB scan malfunctions are more likely to arise precisely when the table has weight on.

REFERENCES

1. National Electrical Manufacturers Association. NEMA NU 1 (1994) Performance measurement of scintillation cameras. Rosslyn, VA: National Electrical Manufacturers Association
2. Murphy P (1987) Acceptance Testing and Quality Control of Gamma Cameras, Including SPECT. J NuclMed 28:1221-1227
3. National Electrical Manufacturers Association. NEMA NU 1 (2001) Performance measurement of scintillation cameras. Rosslyn, VA: National Electrical Manufacturers Association
4. National Electrical Manufacturers Association. NEMA NU 1 (2018) Performance measurement of scintillation cameras. National Electrical Manufacturers Association. Rosslyn, VA
5. Halama J, Graham D, Harkness BA et al. (2019) Acceptance Testing and Annual Physics Survey Recommendations for Gamma Camera, SPECT, and SPECT/CT Systems. American Association of Physicists in Medicine Report 177. New York, NY
6. International Atomic Energy Agency (2009) Quality assurance for SPECT systems. Human Health Series No. 6. International Atomic Energy Agency, Vienna
7. Elliott A (2005) Quality assurance in: Practical Nuclear Medicine. Springer-Verlag, 65-91, London
8. Blokland JA, Camps JA, Pauwels EK (1997) Aspects of performance assessment of whole body imaging systems. Eur J Nucl Med 24(10):1273–83.
9. International Atomic Energy Agency (2003) Quality control atlas for scintillation camera systems. International Atomic Energy Agency. Vienna

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