DIAGNOSTIC IMAGING EUROPE

PET AND PET/CT IN PATIENTS WITH LARGE VESSEL VASCULITIS

COMBINED OPTICAL TOMOGRAPHY AND X-RAY TOMOSYNTHESIS
Research studies show potential in breast screening

MAGNETIC RESONANCE ELASTOGRAPHY
a review of principles and applications

FILTERING IN SPECT IMAGE RECONSTRUCTION

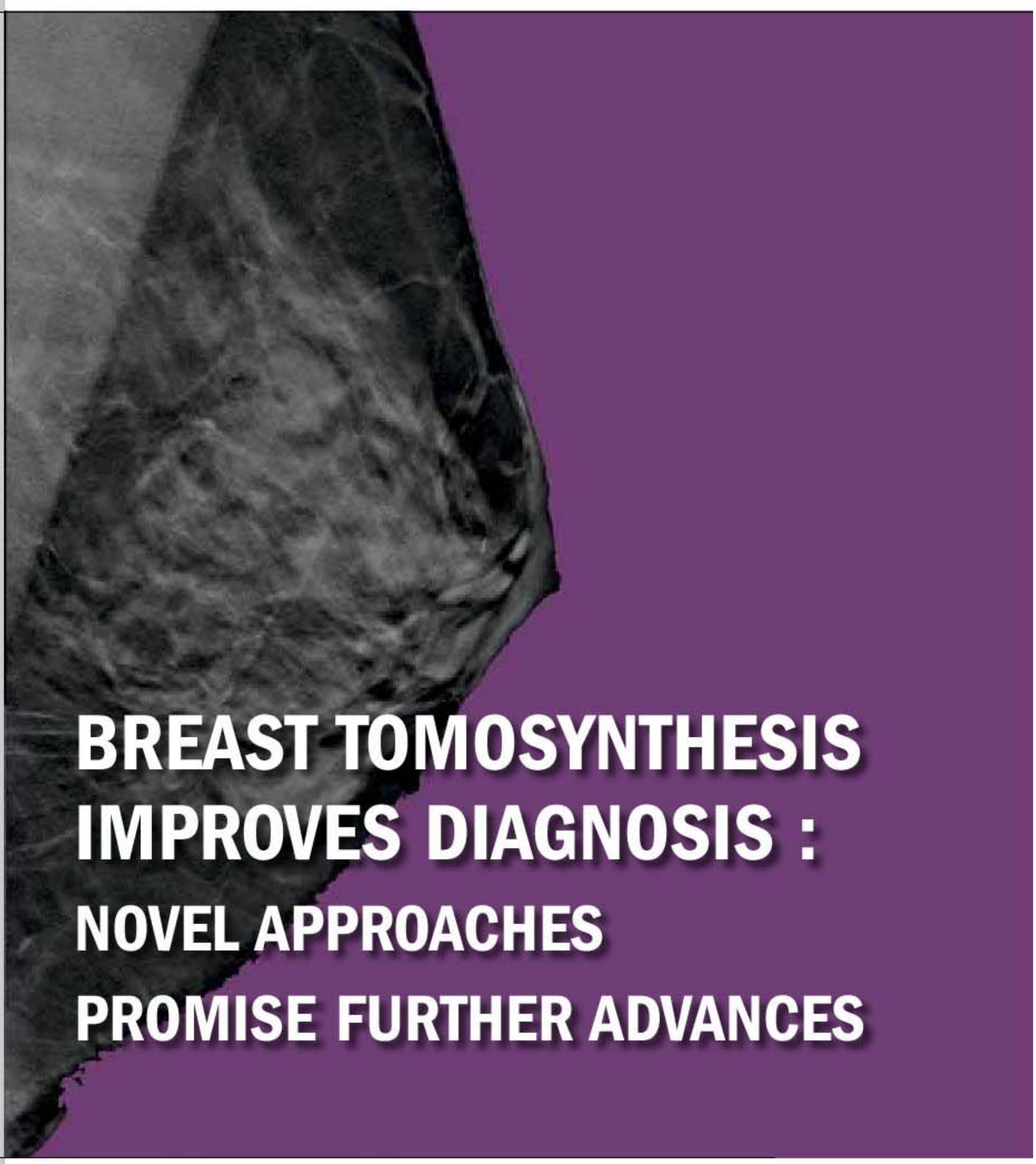
MRI OF THE CHEST
a review of pneumological and other new applications

DIeurope.com

DIAGNOSIS · TECHNOLOGY · THERAPY · PREVENTION

OCTOBER 2011

DIAGNOSTIC IMAGING EUROPE



BREAST TOMOSYNTHESIS IMPROVES DIAGNOSIS :

NOVEL APPROACHES PROMISE FURTHER ADVANCES

BY DR M LYRA AND DR A PLOUSSI

Filtering in SPECT Image reconstruction

Single photon emission computed tomography (SPECT) is widely used in nuclear medical imaging. However the quality of the final tomographic image can be limited by several factors. Image filtering is necessary to compensate for these effects and to improve image quality. The goal of filtering in tomographic images is to suppress statistical noise and simultaneously to preserve spatial resolution and contrast. The choice of the filter type, the cut-off frequency and the order is a headache in clinical routine. This article describes the most commonly used filters and how the selection of the appropriate filters can be made.

THE ROLE AND THE USEFULNESS OF SPECT IMAGING

Single photon emission computed tomography (SPECT) is widely used in nuclear medicine imaging and can play a useful clinical role in the diagnosis and management of several diseases. SPECT is a nuclear medical tomographic imaging that provides a detailed three dimensional (3D) distribution of an administered radioactive tracer within an organ. The radiopharmaceutical agent emits single gamma ray photons. SPECT systems consist of one or more gamma cameras mounted on a gantry so that the detector can rotate around the patient. From the acquired one dimensional projection data from different views around the object, two dimensional (2D) planar projections images are obtained in many evenly spaced angles around the patient and provide an estimate of the 3D distribution of the radiotracer using image reconstruction from multiple projections. The 2D projection images are first corrected for non-unformities and then mathematical algorithms are used to reconstruct 3D matrices of selected planes from the 2D projection data. The most popular methods sfor the reconstruction of tomographic images from acquired data are: filtered backprojection (FBP) and iterative methods [1].

The advantage of SPECT over planar scintigraphy is its ability to acquire the image of the object being examined in slices and separate overlapping structures. As a result, SPECT images have higher contrast and better quality.

THE FACTORS THAT DEGRADE THE SPECT IMAGE

The physical characteristics that determine image qual-0ity are contrast, spatial resolution (detail or sharpness) and noise (statistical and structure). The quality of the final acquired tomographic image is limited by physical factors, such as the limited number of counts, Compton scattering and photon attenuation, and design factors, such as intrinsic and extrinsic spatial resolution of the collimator-detector system and the detection efficiency [2]. These factors can result in blurred images with poor spatial resolution, low contrast and high noise levels.

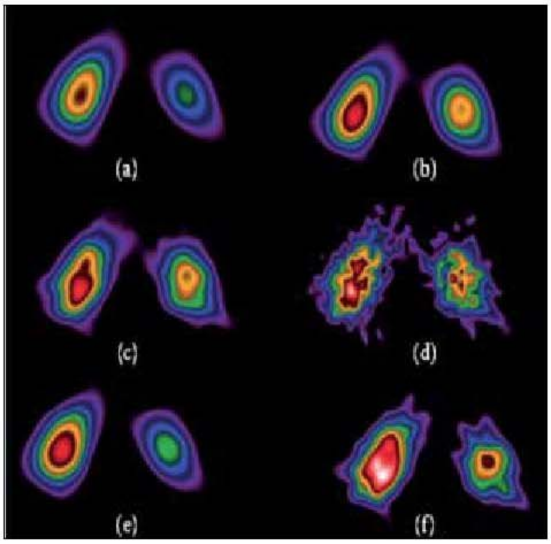


FIGURE 1. : Transverse kidneys; slices reconstructed by different filters result to different effects on the images.
(a) pre-filter Hanning (cut-off 0.8 cm−1), postfilter Ramp.
(b) pre-filter Butterworth (cut-off 0.5 cm−1 power value 10), postfilter Ramp.
(c) pre-filter Butterworth (cut-off 0.8 cm−1, power value 10), post-filter Ramp.
(d) only Ramp pre-filter applied–no other smoothing filter.
(e) pre-filter Ramp, post-filter Hanning (cut off 0.8 cm−1) (f) pre-filter Ramp, post-filter Butterworth (cut-off 0.8 cm−1, power value 10).
Study has been completed in Radiation Physics Unit, Radiology Department, University of Athens.

Maria Lyra and Agapi Ploussi Department of Radiology, Radiation Physics Unit, University of Athens, 76, Vas. Sophias Ave., Athens 11528, Greece

Correspondence to: Maria Lyra, mlyra@med.uoa.gr

THE GOAL OF FILTERING

Image filtering is one of the most important image processing techniques that limit the degradation of the image and affect the quality of clinical SPECT images. Image filtering is a mathematical process by which images are suppressed in noise and also includes smoothing, edge enhancement and resolution recovery. Filters are used during reconstruction and applied to data in frequency domain. The goal of filtering is to compensate for loss of detail in an image while reducing noise. Filters suppress noise as well as deblurr and sharpen the image. The application of filters is the most common method to reduce high-frequency noise component in projection images. In this way, filters can greatly improve the image resolution and limit the degradation of the image.

THE MOST WIDELY USED FILTERS

Different filters are used in SPECT imaging to achieve different purposes such as star artifact reduction, noise suppression, or signal enhancement and restoration.

1. Filtering to reduce the star artifact

Ramp filter. This is a high pass filter that does not permit low frequencies that cause blurring to appear in the image. The ramp is a compensatory filter as it eliminates the star artifact resulting from simple backprojection. A severe disadvantage of high pass filtering is the amplification of statistical noise present in the measured counts. In order to reduce the amplification of high frequencies the ramp filter is always combined with a low pass filter.

2. Filtering to reduce noise

The most common method used to reduce or remove statistical noise in a SPECT image is the application of smoothing filters. These are low pass filters which allow low frequencies to be retained unaltered and block the high frequencies. Low pass filters are characterized mainly by two parameters – the "cut-off frequency" and the "order or power". The cut-off frequency (or roll-off frequency) defines the frequency above which the noise is eliminated. The value of the cut-off frequency determines how the filter will affect both image noise and resolution. A high cut-off frequency will improve the spatial resolution and therefore much detail can be seen but the image will remain noisy. A low cut-off frequency will increase smoothing but will degrade image contrast in the final reconstruction. The parameter order controls the slope of the filter function and characterizes the steepness of the roll off. A high order will result in a sharp fall. Sometimes the term power is used instead of order, with the power being twice the order. There are number of low pass filters that are available for SPECT reconstruction. The most commonly used are discussed below. In Figure 1, the effect of pre- or post-filtering by ramp-Hanning-Butterworth filters is shown, in coronal slices of a SPECT renal study of a 6-month old boy.

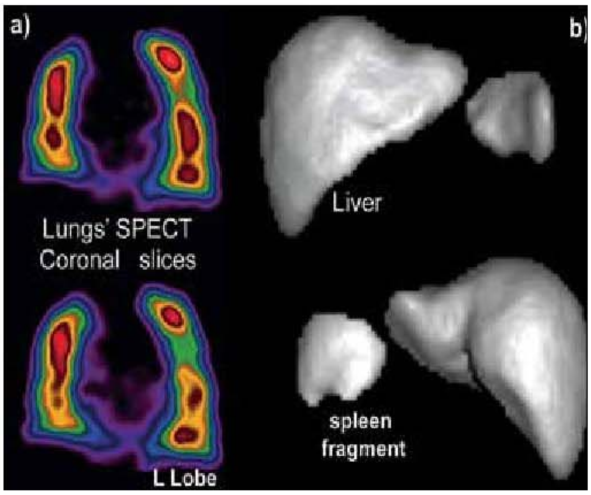


FIGURE 2. : a) Sequential coronal slices show mild pulmonary embolism in left lung lobe (L Lobe) not indicating in planar images. Reconstruction by FBP, Butterworth filter (critical frequency 0.5, order 10)
(M. Gavrilelli, Medical Imaging Center, Athens, Greece).
b) 3D SPECT imaging of liver and spleen fragment -caused by accident-; reconstructed by FBP, pre-filtered by Hanning (critical value 0.8 cm−1) and ramp filter. (Radiation Physics Unit, Radiology Department, University of Athens).

Butterworth. The most usual choice of filters for use in nuclear medicine, the Butterworth filter is a low pass filter that is characterized by two parameters: the critical frequency which is the point at which the filter starts its roll off to zero and the order or power [3].

Hanning. This filter is a relatively simple low pass filter which is described by one parameter, the cut-off frequency [4]. The Hanning filter is very effective in reducing image noise because it reaches zero very quickly however, it does not preserve edges.

Hamming. This is also a low pass filter which presents a high degree of smoothing. The only difference with the Hanning filter is on the amplitude at the cut-off frequency.

Parzen. Yet another example of low pass filter [4]. The Parzen filter is the filter that smoothes the most; it eliminates high frequency noise but it also degrades the image resolution [5].

Shepp – Logan. Another filter that belongs to the family of low pass filters, the Shepp – Logan produces the least smoothing and has the highest resolution [5].

3. Filtering to enhance the signal

A low pass filter may smooth image to a high degree that does not permit discerning small lesions, leading to contrast loss. The restoration filters enhance the signal and in the same time reduces noise without resolution lost. Metz and Wiener are two types of resolution recovery filters that have been used to nuclear medicine.

Metz. This filter is a function of modulation transfer function (MTF) and it is based on the measured MTF of the gamma camera system. The MTF determines how the system handles or degrades the frequencies [6].

Wiener. This filter is based on the signal-to-noise ratio (SNR) of the specific image [7].

PARAMETERS DETERMINING THE CHOICE OF THE SPECT FILTER TYPE

Today, gamma camera systems offer a choice of various filters which may be selected depending on the type of examination.

The filter choice depends on several factors [5, 8]. These are :

- The energy of the isotope, the number of counts and the activity administration.
- The statistical noise and the background noise level.
- The type of the organ being imaged.
- The kind of information we want to obtain from the images.
- The collimator that is used.

The choice of the filter must ensure the best compromise between the noise reduction and the resolution in the image [Figure 2].

Because of the high-count rate and the high SNR in lung or liver SPECT images, filters with a high cut-off frequency are recommended. SPECT imaging and 3D SPECT technique are superior in contrast resolution and improved anatomical detail compared with planar scintigraphy.

FILTER STANDARDIZATION

The choice of filter for a given image reconstruction task is generally a compromise between the extent of noise reduction and fine detail suppression (and of contrast enhancement in some cases) as well as the spatial frequency pattern of the image data of interest.

The selection of the optimal filter and the determination of filter parameters for any individual case remains one of the main problems of filtering in SPECT image processing. In particular the selection of the cut-off frequency is important in order to reduce noise and preserve the image details. Proper filter selection is necessary for the improvement of image quality and therefore for the diagnostic evaluation. However, no filter is perfect and there is no specific filter for all applications. In the literature there are only a few reports for the selection of the appropriate filter parameters, as the conclusions of filter application per organ reconstruction in emission tomography cannot be extended and generalized. The standardization of image-processing results may limit the filter types for each SPECT examination to a few filters and some of their parameters. Standardization also helps to reduce the image processing time, as the filters and their parameters must be standardised before being put to clinical use.

REFERENCES

[1] P. P. Bruyant, "Analytic and iterative reconstruction algorithms in SPECT,"Journal of Nuclear Medicine, 2002; vol. 45, no. 10 : pp. 1343–1358,

[2] B. M. W. Tsui, "The AAPM/RSNA physics tutorials for resident," Radiographics, 1996; vol. 16, no. 1: pp. 173–183,

[3] M.M. Khalil, Ed., Basic Sciences of NuclearMedicine, Springer, Berlin, Germany, 2010.

[4] M. N. Salihin Yusoff and A. Zakaria, "Determination of the optimum filter for qualitative and quantitative 99mTc myocardial SPECT imaging," Iranian Journal of Radiation Research 2009; vol. 6, no. 4: pp. 173–181.

[5] K. van Laere, M. Koole, I. Lemahieu, and R. Dierckx, "Image filtering in single-photon emission computed tomography: principles and applications," Computerized Medical Imaging and Graphics 2001; vol. 25, no. 2: pp. 127–133, .

[6] M. A. King, S. J. Glick, B. C. Penney, R. B. Schwinger, and P. W. Doherty, "Interactive visual optimization of SPECT pre reconstruction filtering," Journal of Nuclear Medicine, 1987; vol. 28, no. 7 : 1192–1198, .

[7] J. M. Links, R. W. Jeremy, S. M. Dyer, T. L. Frank, and L. C. Becker, "Wiener filtering improves quantification of regional myocardial perfusion with thallium-201 SPECT," Journal of Nuclear Medicine 1990; vol. 31, no. 7:1230–1236, .

[8] G. V. Heller, A. Mann, and R. C. Hendel, Nuclear Cardiology: Technical Applications, McGraw-Hill, New York, NY, USA, 2009.

CALENDAR OF EVENTS

Journées françaises de Radiologie (JFR)
21 – 25 Octobre 2011
Paris Porte Maillot
Paris, France.
http://www.sfrnet.org/jfr/JFR2011/

Medica 2011
16 – 19 November 2011
Messe Düsseldorf,
Düsseldorf, Germany
http://www.medica-tradefair.com/

RSNA 2011
27 November – 2nd December 2011
McCormick Place,
Chicago, Il USA
http://rsna2011.rsna.org/

Erasmus Course on Magnetic Resonance Imaging
MRI of the Joints (from Finger to toe)
16 20 January 2012
Brussels, Belgium
www.emricourse.org

Arab Health Exhibition
Arab Health Congress
23 – 26 January 2012
Dubai International Convention & Exhibition Centre
Dubai
United Arab Emirates
http://www.arabhealthonline.com/

Adanced Breast Diagnostics
27 – 28 January, 2012
International Breast Ultrasound School Course
Technopark Zürich, Switzerland
http://www.senologie.ch/

Korean International Medical and Hospital Equipment Shows (KIMES)
18 – 21 Mar 2012
COEX Korea Exhibition Center
Seoul, Korea.
http://www.kimes.kr/

ECR
European Congress of Radiology
March 1 -5, 2012
Austria Center Vienna
Bruno-Kreisky-Platz 1
1220 Vienna, Austria
http://www.myesr.org/

ECIO 2012 –
Third European Conference on Interventional Oncology
April 25 - 28, 2012
Florence, Italy
http://www.ecio2012.org/

Dates and descriptions of future events have been obtained from usually reliable official industrial sources. DiE can not be held responsible for errors, changes or cancellations.