Quantification of Right-to-Left Cardiac Shunt

VJR Schelfhout, Rijnstate, Arnhem

1. Introduction

In cardiac abnormalities with right-to-left (R-L) shunts oxygen-poor blood flows from the right side of the heart into the left side and thus into the systemic circulatory system. A R-L shunt results in abnormally reduced pulmonary blood flow and a substantial amount of blood does not get oxygenated resulting in cyanosis and hypoxia.
Some examples of R-L shunts are pulmonary (valve) stenosis with ASD or with VSD, Tetralogy of Fallot, Eisenmenger's syndrome, tricuspid atresia and pulmonary arteriovenous malformations. Quantification of R-L shunts is important both in the diagnosis and follow-up after therapy.
Macroaggregates of albumin or albumin microspheres which are normally trapped in the pulmonary capillaries pass through the R-L shunt into the systemic circulation.

2. Methodology

This guideline is based on available scientific literature on the subject, the previous guideline (Aanbevelingen Nucleaire Geneeskunde 2007), international guidelines from EANM and/or SNMMI if available and applicable to the Dutch situation.

3. Indications

a. Diagnosis in cyanotic disease
b. Follow-up after treatment

4. Relation to other diagnostic procedures

a. 100% oxygen breathing method

After breathing 100% oxygen for 15 to 20 min, to allow full wash-out of nitrogen from the alveoli, arterial blood gas and oxygen saturation are measured. By measuring the oxygen saturation in the right atrium and arteria pulmonalis (right heart catheterization) in comparison with the oxygen saturation in the left system the shunt can be detected. The shunt fraction is calculated by Flamm's method. A shunt fraction of >5% is considered abnormal and warrants additional evaluation.
Studies have shown excellent agreement in shunt fraction between the nuclear medicine technique and the 100% oxygen method.

b. Contrast echocardiography (bubble echocardiogram)

Contrast echocardiography involves the injection of echocardiographic contrast (e.g. agitated saline) into a peripheral vein, while simultaneously imaging the right and left atria with two-dimensional echocardiography. Microbubbles visualized within 1 to 2 cycles in the left atrium imply an intracardiac shunt rather than an intrapulmonary shunt. In the absence of a shunt, microbubbles are filtered by the pulmonary capillaries. It is a safe screening test in the pediatric population with a sensitivity of 100% and specificity between 67 and 91%.

5. Medical information necessary for planning

a. Indication
b. Clinical manifestations (e.g. heart sounds, murmurs,..)
c. Echo-doppler findings
d. Angiocardiography findings

6. Radiopharmaceutical

Tracer:	^{99m}Tc-macroaggregates of albumin (MAA)
Nuclide:	Technetium-99m
Activity:	100 MBq
Administration:	intravenous in an antecubital vein

7. Radiation safety

a. Pregnancy

The radiation dose to the unborn child is approximately equal to the radiation dose to the uterus. ^{99m}Tc-MAA: 0,0022 mGy/MBq.

b. Lactation

Breast feeding should be interrupted for 12 h according to ICRP 106.

c. Radiation exposure ^{99m}Tc-MAA: 0,011 mSv/MBq for adults and 0,016 to 0,063 mSv/MBq for children depending on age.

8. Patient preparation/essentials for procedure

Before administration shake the syringe. Administration of the radiopharmaceutical should be with the patient in supine position. Patients should inhale and exhale deeply before, during and after administration of the radiopharmaceutical. No blood should be drawn into the syringe before administration, as this may cause macroaggregates to form in the synringe.

9. Acquisition and processing

Energy:	^{99m}Tc, 140 keV
Window:	15-20%
Collimator:	LEAP
Counts:	300 sec per view
Computer:	300 sec per frame, matrix 128x128

Total body anterior and posterior acquisitions. Non-overlapping regions of interest (ROI's) are drawn over the lungs (CL) and the rest of body (CTL). Activity due to extravasation at the injection site should be excluded from the CTL-ROI. The shunt fraction can be calculated with following formula:

RL=(CTL/CTL+CL) x 100%

An alternative method is calculation of brain and kidney-uptake (under physiological situations this will equal one third of cardiac output). Shunt fraction can be calculated as:

RL= (3 x CKB/ 3 x CKB + CL) x 100%

RL= R-L shunt, CKB= counts in kidneys and brain, CL= counts in lungs

10. Interpretation

a. There will be an overestimation of the shunt fraction when the investigation is performed on a crying child. The reason being increased resistance in the pulmonary capillaries.
b. Free pertechnetate (resulting in accumulation in urine bladder, stomach and thyroid gland) leads to an overestimation.
c. In a R-L shunt activity is seen in lungs, thyroid gland, brain, kidneys, spleen and myocardium.
d. Total pulmonary-venous backflow results in a false-negative outcome as all particles are trapped in the lungs, usually due to a foramen ovale.
e. A positive result is also seen in patients with pulmonary hypertension and a patent foramen ovale (without structural congenital heart-disease)

11. Report

Description of the distribution of ^{99m}Tc-MAA on the anterior and posterior acquisitions and the calculated fraction.

12. Literature

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