

## Supplementary material

### Methods of oropharyngo-esophageal scintigraphy (OPES)

OPES provides a rapid sequence of images of voluntary swallowing acts performed by the patient on request. Fasting at least 3 h prior to the examination is required. To get used to the procedure, the patient first swallows about 10 mL of non-radioactive water. The investigation then starts with the subject in standing position and with the face in an 80° oblique projection in front of a large-field-of-view  $\gamma$ -camera equipped with a low-energy parallel hole collimator and an energy window on 140 keV ( $\pm 10\%$ ). The patient is then given a single 10 mL bolus of water labelled with 37 MBq of  $^{99m}\text{Tc}$  nanocolloid (Curium, UK). Eight images per second are acquired (0.125 s/frame) for 1 min, with dynamic acquisitions (64  $\times$  64 matrix and zoom 1) of the visual fields from the oral cavity down to the epigastric area. Two seconds after the beginning of the procedure, the patient is asked to swallow the liquid in one gulp. With the subject remaining in the same position, a 60 s lasting static image is acquired at the end of the examination, to evaluate the presence of a possible tracheobronchial aspirate. At the end of the procedure, the possible presence of multiple swallows is assessed, as these would not allow an ac-

curate semi-quantitative analysis. The examination is then repeated after an interval of 30 min, with a 10 mL “jelly drink” semisolid bolus (Resource Bevanda Gelificata, Novartis S.A.®) labelled with 37 MBq of  $^{99m}\text{Tc}$  nanocolloid. Scintigraphic acquisitions are then performed in the same way as for the liquid bolus.

Cine-mode (qualitative) visual analysis of the images acquired during bolus swallowing allows the identification of abnormal patterns, especially for the site of bolus retention, discriminating between the upper third and the middle-lower thirds of the oesophagus.

Semi-quantitative analysis instead involves the calculation of the oropharyngo-esophageal transit time of the radioactive bolus, with manual definition of the regions of interest (ROI) for oral cavity, pharynx, and oesophagus. The semi-quantitative parameters are derived from the activity/time curves obtained on the marked ROIs:

- Oropharyngeal transit time (OPTT): the time required for the bolus to leave the oral cavity and the pharynx from the beginning of swallowing.
- Oesophageal transit time (ETT): the interval between bolus entry and its exit through the oesophagus
- Oropharyngeal and esophageal retention index (OPRI and ERI): the residual radioactive bolus fraction in each tract 10 s after swallowing.

The following table reports normal OPES threshold values:

OPES parameter	Normal value
OPTT	$\leq 1.2$ s
ETT	$\leq 10$ s
OPRI	$< 5\%$
ERI	$< 20\%$

Based on those cut-offs, a retention score was developed:

Retention index	
OPRI score 0	$< 5\%$
OPRI score 1	5-20%
OPRI score 2	$> 20\%$
ERI score 0	$< 20\%$
ERI score 1	20-40%
ERI score 2	40-60%
ERI score 3	$> 60\%$