

Medical calibrators quality assurance and testing

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ABSTRACT

Radionuclides commonly used in nuclear medicine in Romania include Tc-99m, I-131, and F-18. These radionuclides are measured at Ionizing Radiation Metrology Laboratory (LMRI) from National Institute for R&D in Physics and Nuclear Engineering "Horia Hulubei" (IFIN-HH) using an ionisation chamber that serves as a secondary standard. LMRI ensures the national metrological traceability and its international equivalence through regular participation in international comparisons of activity measurement, the most recent of which took place in 2023. Following calibration at LMRI, the activity of the radioactive solutions is measured using the dose calibrators available from the customers. The stability of the chamber functioning is verified using a Cs-137 standard radioactive solution. The radionuclides used in nuclear medicine have relatively short half-lives which makes them well suited for diagnostic and therapy applications, as they result in reduced exposure to ionising radiation. In this study, various types of calibrators are evaluated by assessing their performance regarding two main criteria: the ratio between measured activity and the conventionally true value and the linearity check.

EXPERIMENTAL SETUP



Fig. 1. Medical calibrators calibrated at LMRI [1-3]: a) Capintec; b) Curiementor 3; c) Curiementor 4; d) Comecer

RESULTS

Characteristics	CAPINTEC	CURIEMENTOR 3	CURIEMENTOR 4	COMECER
Measuring interval	0.1 MBq - 200 GBq (Tc-99m)	0.1 MBq - 195 GBq (Cs-137)	0.1 MBq - 195 GBq (Cs-137)	0.001 MBq - 200 GBq (Tc-99m)
Resolution	0.001 MBq	0.001 MBq	0.001 MBq	0.001 MBq
Reproducibility	≤ 3 %	≤ 5 %	≤ 5 %	± 1 % over 24 hours
Linearity	± 2 %	± 2 %	± 2 %	± 1 %

Between 2015 and 2026, a systematic study was conducted on the time evolution of the performance of four types of calibrators used in nuclear medicine laboratories in Romania: Capintec CRC-55R, Curiementor 3, Curiementor 4 and Comecer.

The results are shown in the table below, where R represents the ratio between A_m (measured value of activity) and A_{ca} (conventionally true activity):

$$R = \frac{A_m}{A_{ca}}$$

The absolute uncertainties were calculated using the error propagation formula:

$$\sigma_R = R \cdot \sqrt{\left(\frac{\sigma_{A_m}}{A_m}\right)^2 + \left(\frac{\sigma_{A_{ca}}}{A_{ca}}\right)^2}$$

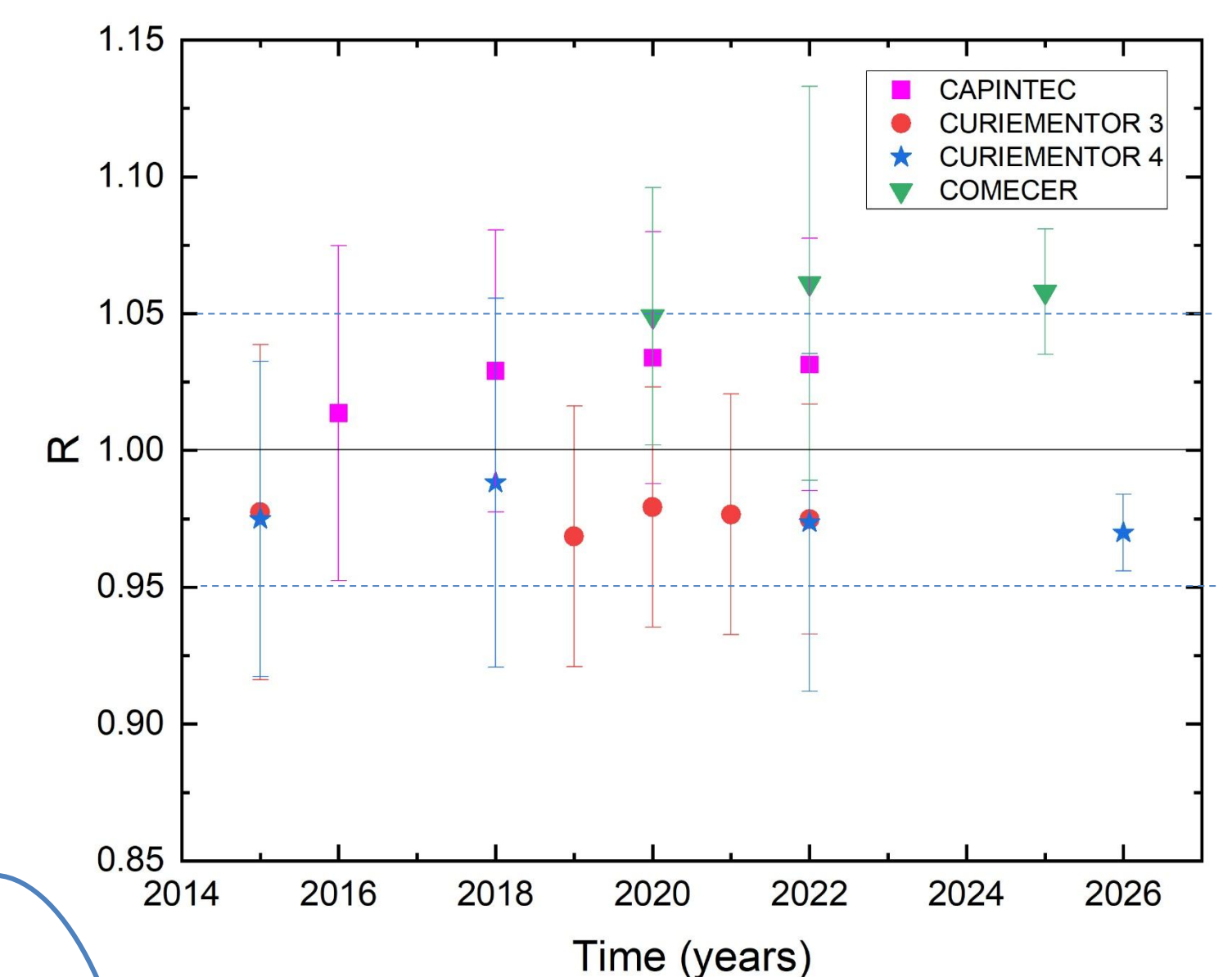


Fig. 2. Performance over time of the 4 calibrators

Steps for calibrating a radionuclide calibrator in LMRI [4, 5]:

- Measure background using the ionization chamber.
- Measure a Cs-137 solution with the ionization chamber to check stability.
- Calibrate a Tc-99m solution using the ionization chamber.
- Calibrate the radionuclide calibrator by measuring the reference solution.

After step iv), two cases may occur:

- The difference between the activities is ≤ 10%: compare this difference with the combined uncertainty of the ionization chamber and the calibrator; confirm it falls within the instrument's uncertainty limits.
- The difference is > 10%: calculate a correction factor (conventionally true activity divided by activity measured using the calibrator) and include it in the calibration certificate.

- Check linearity by measurements over ~24 hours, covering at least one order of magnitude decrease in activity.

CAPINTEC		CURIEMENTOR 3		CURIEMENTOR 4		COMECER	
Time relative to the reference moment	Rel. diff.	time	Rel. diff.	time	Rel. diff.	time	Rel. diff.
4 mins	0.00 %	2 mins	0.00 %	4 mins	0.00 %	4 mins	0.00 %
2 h 16 mins	0.82 %	2 h 25 mins	-0.47 %	3 h 35 mins	-0.37 %	3 h 14 mins	0.4 %
18 h 57 mins	-0.25 %	19 h 29 mins	-1.04 %	22 h 1 min	-0.16 %	21 h 5 min	0.9 %
20 h 13 mins	0.00 %	24 h 11 mins	0.42 %	26 h 18 mins	-0.51 %	35 h 7 min	1 %

Linearity check of calibrators

From the adjacent table, it can be observed that the difference between the measured activity and the conventionally true value of it are within ± 6%.

It can also be noticed that the long-term stability (2015-2026) of the calibrators is better than 0.9%.

Linearity was verified by measurements at different time intervals, covering a total period of 24 hours. The table shows that linearity is satisfactory, with deviations within 1%.

Calibration year	CALIBRATOR type											
	CAPINTEC			CURIEMENTOR 3			CURIEMENTOR 4			COMECER		
	A_m (MBq)	A_{ca} (MBq)	R	A_m (MBq)	A_{ca} (MBq)	R	A_m (MBq)	A_{ca} (MBq)	R	A_m (MBq)	A_{ca} (MBq)	R
2015	-	-	-	1899 ± 104	1943 ± 59	0.977 ± 0.061	1050 ± 53	1077 ± 33	0.975 ± 0.058	-	-	-
2016	1340 ± 70	1322 ± 40	1.014 ± 0.061	-	-	-	-	-	-	-	-	-
2018	162.9 ± 6.5	158.3 ± 4.8	1.029 ± 0.052	-	-	-	176 ± 10.8	178.1 ± 5.3	0.988 ± 0.067	-	-	-
2019	-	-	-	141.5 ± 5.5	146.1 ± 4.4	0.969 ± 0.048	-	-	-	-	-	-
2020	170.8 ± 6.8	165.2 ± 3.3	1.034 ± 0.046	132.1 ± 5.3	134.9 ± 2.7	0.979 ± 0.044	-	-	-	200.9 ± 8.0	191.5 ± 3.8	1.049 ± 0.047
2021	-	-	-	158.9 ± 6.4	162.7 ± 3.3	0.977 ± 0.044	-	-	-	-	-	-
2022	142.52 ± 5.69	138.18 ± 2.77	1.031 ± 0.046	310 ± 12	318 ± 6	0.975 ± 0.042	162.8 ± 9.8	167.2 ± 3.3	0.974 ± 0.062	160.8 ± 9.7	151.6 ± 4.6	1.061 ± 0.072
2025	-	-	-	-	-	-	-	-	-	443.4 ± 6.7	418.9 ± 6.3	1.058 ± 0.023
2026	-	-	-	-	-	-	324.0 ± 3.3	333.9 ± 3.3	0.970 ± 0.014	-	-	-

CONCLUSIONS

- All measurements performed with the four types of calibrators showed deviations of less than ± 6 % relative to the LMRI certified reference values.
- Overall, the time evolution of their operational performance demonstrates excellent stability, confirming the reliability of these instruments for routine use in nuclear medicine field.
- The results obtained in this work confirm that the relative calibration method using Centronic Ionization Chamber provides excellent calibration precision and very good long-term stability.

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