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Comparison of Tc-99m Measurements in UK Hospitals, 2006

Desmond MacMahon, Jo Townley, Eleanor Bakhshandeiar, Arvic Harms

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Comparison of Technetium-99m Measurements in UK Hospitals, 2006

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Abstract

To assess the current accuracy of clinical measurements of the activity of $^{99}Tc^{m}$, a comparison has been conducted between measurements at the National Physical Laboratory (NPL) and measurements made within the United Kingdom hospital physics community. Measurements were carried out within the period 3rd – 19th October and on 4th December 2006. The October sources were measured at NPL before distribution. The December source was measured at NPL after the hospital measurements.

Two hundred and eleven results were reported for this comparison from forty-eight participating hospitals, or groups of hospitals. Of these results 96% were within 5% of the NPL value. Only one measurement deviated by more than 10% from the NPL value. The standard deviation of all the results relative to the NPL value was 2.4%. All October results are for 10R Schott vials containing approximately 4 ml of solution; the December results were for a P6 vial containing 3.9 ml of solution.

The results of this comparison are encouraging, indicating that the accuracy of hospital measurements of $^{99}Tc^{m}$, in the large majority of cases, is now better than 5%.

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1 INTRODUCTION

Radioactive materials are widely used in hospitals for therapeutic, diagnostic and research purposes. The choice of radionuclide depends on the type of radiation emitted as well as its expected pathway through the body. The activity should be determined accurately prior to administration to the patient. Radionuclide calibrators are the most commonly used instruments for radionuclide activity assay; they are normally based on high pressure, re-entrant ionisation chambers. Calibration factors for solution formats are determined directly by measuring the ionisation chamber response to solutions that have been standardised using absolute methods. The operation of such radionuclide calibrators is relatively straightforward and, if used correctly in conjunction with a recognised quality assurance system, the relevant levels of accuracy can be achieved. A protocol for such a QA system has been recommended for use in UK hospitals[1].

As part of its ongoing programme, supported by the National Measurement System Policy Unit of the Department of Trade and Industry, the National Physical Laboratory's Radioactivity Metrology Group is conducting a series of comparisons and workshops concerned with the use of radionuclide calibrators in practice. This continues the well-subscribed comparisons conducted in previous years [2-10]. The aim is to determine the overall level of measurement performance in UK hospitals, to identify and discuss problems and to facilitate the exchange of information.

$^{99}Tc^{m}$ is the most widely used radionuclide in diagnostic nuclear medicine. Approximately half a million patients are investigated every year in the United Kingdom. An accurate determination of the activity administered enables the radiation dose delivered to the patient to be as low as possible, consistent with obtaining a high quality image.

In February 2005, a primary standardisation of $^{99}Tc^{m}$ was performed at NPL on a solution that was also transported to the Bureau International des Poids et Mesures in Paris and measured in the SIR (International Reference System) ionisation chamber. The SIR enables primary standards from national measurement institutes worldwide to be compared, giving additional confidence in their accuracy. The BIPM Key Comparison results are shown in Figure 1. The NPL $^{99}Tc^{m}$ submission was within

0.14% of the SIR key comparison reference value and the new standardisation has not, therefore, changed the calibration factor for the NPL radionuclide calibrator.

This report presents the results of the latest comparison, carried out in late 2006 within the United Kingdom, to assess the current situation regarding $^{99}Tc^{m}$ activity measurements and provides hospitals with a traceable standard, enabling them to re-calibrate their systems.

2 PARTICIPANTS

A total of 48 hospitals took part in the comparison, reporting a total of 211 individual measurements. A list of the participants is given in Appendix 1.

3 COMPARISON SAMPLES

The stock solution was milked from a ^{99}Mo generator, diluted and accurately subdivided into 10R Schott vials. The samples, each comprising approximately 4 ml of solution, were then assayed at NPL and dispatched on a Monday evening for delivery at hospitals on a Tuesday morning. Because of the large number of participants 3 generators were used and sources dispatched on Mondays 2nd , 9th and 16th October. A few further sources were dispatched on Wednesday 18th October for delivery and measurement on Thursday 19th October. All NPL measurement results were decay corrected to 12:00 GMT on 3rd, 10th, 17th or 19th October as appropriate. For this comparison, the activity of each sample is given in Table 1. A total of 47 sources was dispatched. In one further case, in December, a P6 vial was dispensed in a hospital, measured in a range of instruments and sent to NPL for measurement the following day.

4 NPL MEASUREMENTS OF COMPARISON SAMPLES

The activity concentration of each sample was determined by assay on NPL's master SSRC (it should be noted that this system has also been known in the past as the NPL-CRC, 671/271 chamber and Isocal IV). This system has been previously calibrated for $^{99}Tc^{m}$ using solutions which have been standardised absolutely using the primary standardisation facilities and techniques available at NPL.

A sample from each batch was measured by gamma spectrometry to identify and quantify any contaminant in the sample. No ^{99}Mo nor any other gamma ray emitting radionuclide was detected in any of the 10R Schott vials, with a ^{99}Mo detection limit of approximately 1 kBq. The P6 vial (December measurements) contained a trace of ^{99}Mo, negligible compared to the ^{99}Tc^{m} activity (2.4 kBq ^{99}Mo in 629 MBq ^{99}Tc^{m} on the day of the hospital measurements; 1.9 kBq ^{99}Mo in 39 MBq ^{99}Tc^{m} on the day of the NPL measurement). The uncertainties of all the NPL ^{99}Tc^{m} activity measurements were 0.9% ($k=1$).

5 MEASUREMENT AND REPORTING PROTOCOL

Participants were asked to assay the ^{99}Tc^{m} solution on their calibrators and to report their results back to NPL.

The preferred format for this comparison was the 10R Schott vial; a P6 vial was used in only one case. Participants were asked to report the details of their radionuclide calibrator and the ^{99}Tc^{m} calibration or dial factor setting used. Details of uncertainty calculations were also asked for. A standard reporting form was provided, a copy of which is shown in Appendix 2.

The results were collated and analysed by NPL. After submission of their results to NPL, each participant received a certificate showing the NPL measured activity at a reference time of noon GMT on the date of the hospital measurement. Each reported hospital measurement has been decay corrected from the time of measurement to that same reference time. Results are reported as the ratio (Hospital Measurement/NPL Measurement). The first problem encountered in the analysis of results was that it became clear that several participants had reported a measurement time in BST rather than GMT as requested on the reporting form. It was, thus, necessary to ask every participant to confirm which time basis was reported. In retrospect the reporting form could have been designed to make this distinction clearer. In the case of ^{99}Tc^{m}, decay of one hour leads to a 10% decrease in activity.

6 CONFIDENTIALITY

All results were reported directly to NPL. Each reported result was given a code number by NPL and the results in this report are tabulated against those code numbers. The correlation between code number and the participant remains confidential to NPL and the individual participant.

7 RESULTS

A total of 211 measurement results was returned from 48 participants representing 8 different manufacturers and a total of 19 different models.

Table 1 shows the complete set of results, including: -

- hospital measurements decay corrected to noon GMT on the day of measurement, with uncertainties where they were quoted;
- NPL measurements decay corrected to that same reference time;
- the ratio (Hospital Measurement/NPL Measurement);
- E_n values, where E_n is as defined in reference (11): -
- $E_n = \frac{x_n - x_{NPL}}{\sqrt{\sigma_n^2 + \sigma_{NPL}^2}}$ where x_n is the hospital value and σ_n its associated expanded (k=2) uncertainty; x_{NPL} is the NPL value and σ_{NPL} its associated expanded (k=2) uncertainty (1.8%);
- where the hospital has not quoted an uncertainty there is no corresponding E_n value.

All decay corrections were made using 6.0067 hours (0.25028 days) as the $^{99}Tc^m$ half-life [12].

The data of Table 1 are shown graphically in Figure 2 where the y-axis is the ratio (Hospital Measurement/NPL Measurement) and the x-axis is the individual measurement identification number. Figure 3 shows the same data ordered by the magnitude of the ratio, while Figure 4 presents the data as a histogram, showing the number of results in each 0.005 interval of the ratio.

Figures 5 – 14 show sub-sets of the data broken down by date of measurement (figs. 5 – 9) or by type of calibrator (figs. 10 – 14). Table 2 shows the mean ratios and standard deviations of each subset of results.

8 DISCUSSION

There were two main aims of this exercise. The first was to assess the current accuracy of $^{99}Tc^{m}$ activity measurements in hospitals using typical radionuclide calibrators; the second was to provide participants with a traceable standard enabling them to check the performance of their systems and to recalibrate their systems if necessary.

8.1 ALL RESULTS

The distribution of results is as follows:

Within 2 % of the NPL value:	64%
Within 5 % of the NPL value:	96%
Within 10 % of the NPL value:	99.5%

The mean (Hospital Measurement/NPL Measurement) ratio of all data is 1.0104 ± 0.0017 with a standard deviation of 2.4%, indicating a high level of consistency within the hospital measurements. The median of all data is similar to the mean: 1.0100 ± 0.0015. It is, thus, clear that the mean ratio is significantly different from unity. This is also clear from Figures 2, 3 and 4. A Wilcoxon signed rank test [11], applied to the data, results in t = 6.94, confirming that the data do not come from a symmetrical population with a median value of 1. It is interesting to note that the NPL calibration factor for a 10R Schott vial is greater than that of a P6 vial by a factor of 1.010, so that a difference between the 10R Schott vial and the vials used by the manufacturers to establish the $^{99}Tc^{m}$ preset calibration factors could lead to a ratio different from 1.

8.2 RESULT SUBSETS

Measurements were carried out on four dates in October 2006 and one date in December. Figures 5 – 9 and Table 2 show that there were no significant differences between the measurements on the four dates.

Figures 10 – 14 and Table 2 show a breakdown by calibrator manufacturer. The mean ratio for the Veenstra calibrators at 1.028 is slightly higher than the overall mean of 1.010. Vinten calibrators and "other" calibrators (i.e. not Capintec, Vinten or Veenstra) are characterised by mean ratios very close to unity (both 1.000) and by increased standard deviations (3.6% and 4.1% respectively).

8.3 CALIBRATION FACTORS

The calibration factors quoted on the reporting forms are listed in Table 1. In the majority of cases a manufacturer's recommended dial setting or calibration factor for $^{99}Tc^{m}$ was used. For most Capintec calibrators a calibration factor of 080 was used, but other factors from 079 to 093 have been reported, derived from earlier calibrations.

There were several different types of radionuclide calibrators and models used for this comparison. In many cases, the different model identifiers relate to the electronics, with the same ionisation chambers being used. One hundred and sixty-eight measurements (80% of the total) were carried out on Capintec systems, including CRC 15R, CRC 15R beta, ARC 120R, CRC 10R and 15W. One hundred and fifty-three of the Capintec measurements used a calibration factor reported either as 080 or as manufacturers preset for $^{99}Tc^{m}$; these produced a mean ratio of 1.011 as shown in Table 2. The remaining fifteen Capintec measurements with other calibration factors produced an improved mean ratio of 1.003.

8.4 UNCERTAINTIES

There was considerable variation in the reporting of uncertainties, making a full statistical analysis of the data impossible. Seventy-one measurements (34% of the total) were reported without uncertainty information.

Forty-one measurements (19% of the total) were reported with type A uncertainties, quoted mainly as results of reproducibility of repeated measurements. Such uncertainties were in the range 0.1% – 0.3 % and lead to large E_n values in Table 2.

Ninety-one measurements (43% of the total) reported both type A and type B uncertainties. Such uncertainties were mostly in the range 3% – 5% and appear realistic in terms of the spread in the data. A few measurements quoted uncertainties in the range 6% - 17%. These produce small E_n values in Table 2 and appear to be pessimistic.

The remaining eight measurements (4% of the total) reported only type B uncertainties.

9 CONCLUSIONS

This comparison has determined the accuracy of $^{99}Tc^m$ measurements in UK hospitals.

(a) The overall result of the comparison is encouraging, indicating that the majority of UK hospitals achieve an accuracy better than 5% in the measurement of $^{99}Tc^m$. Of the original results 96% fell within 5% of the NPL value and 64% were within 2% of the NPL value.

(b) Uncertainties of measurements were not adequately assessed by many participants.

(c) Radionuclide calibrators should be recalibrated individually using traceable standards, in the preferred format i.e. 10 R Schott vial.

(d) When manufacturers calibration factors are used, care should be taken to ensure that the container formats are the same.

(e) Users should ensure that the recommended quality assurance procedures are established and maintained on a regular basis.

10 ACKNOWLEDGEMENTS

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The participants are thanked for the time and effort they have put into this exercise.

Thanks are also due to many members of the Radioactivity Metrology Group at NPL for their support.

11 REFERENCES

(1) *NPL Measurement Good Practice Guide No. 93: Protocol for Establishing and Maintaining the Calibration of Medical Radionuclide Calibrators and their Quality Control (2006).* Available free on the following web site: http://publications.npl.co.uk/npl_web/pdf/mgpg93.pdf

(2) M J Woods.
Intercomparison of ^{57}Co and ^{125}I in U.K. Hospitals 1980/81.
NPL Report RS56 (1981).

(3) M J Woods.
Intercomparison of ^{99m}Tc and ^{131}I by Radionuclide Calibrators in U.K. Hospitals, 1986.
NPL Report RS(EXT)88 (1987).

(4) M J Woods, J D Keightley, M Ciocanel.
Intercomparison of ^{67}Ga Solution Sources in U.K. Hospitals, 1996.
NPL Report CIRA(EXT)012.

(5) M J Woods, M Ciocanel, J D Keightley.
Intercomparison of ^{123}I Solution Sources in U.K. Hospitals, 1996.
NPL Report CIRA(EXT)017 (1997).

(6) M J Woods, M Ciocanel, J D Keightley.
Intercomparison of ^{111}In Solution Sources in U.K. Hospitals, 1997.
NPL Report CIRM 001 (1997).

(7) M Ciocanel, J D Keightley, C J Scott and M J Woods.
Intercomparison of ^{131}I Solution and Capsule Sources in U.K. Hospitals, 1999.
NPL Report CIRM 31 (1999).

(8) M Baker and M J Woods.
Intercomparison of ^{123}I Solution Sources in U.K. Hospitals, 2000.
NPL Report CIRM 38 (2000).

(9) M Baker and M J Woods.
Intercomparison of ^{201}Tl Solution Sources in U.K. Hospitals, 2001.
NPL Report CIRM 47 (2001).

(10) D.K. Tyler, M.I. Baker, M.J. Woods
Comparison of Strontium-89 Solution Sources in UK Hospitals, 2003
NPL Report DQL-RN 012 (2005).

(11) British Standard.
Statistical methods for use in proficiency testing by interlaboratory comparisons
BS ISO 13528:2005

(12) *Decay Data Evaluation Project (DDEP)*
http://www.nucleide.org/DDEP_WG/DDEPdata.htm

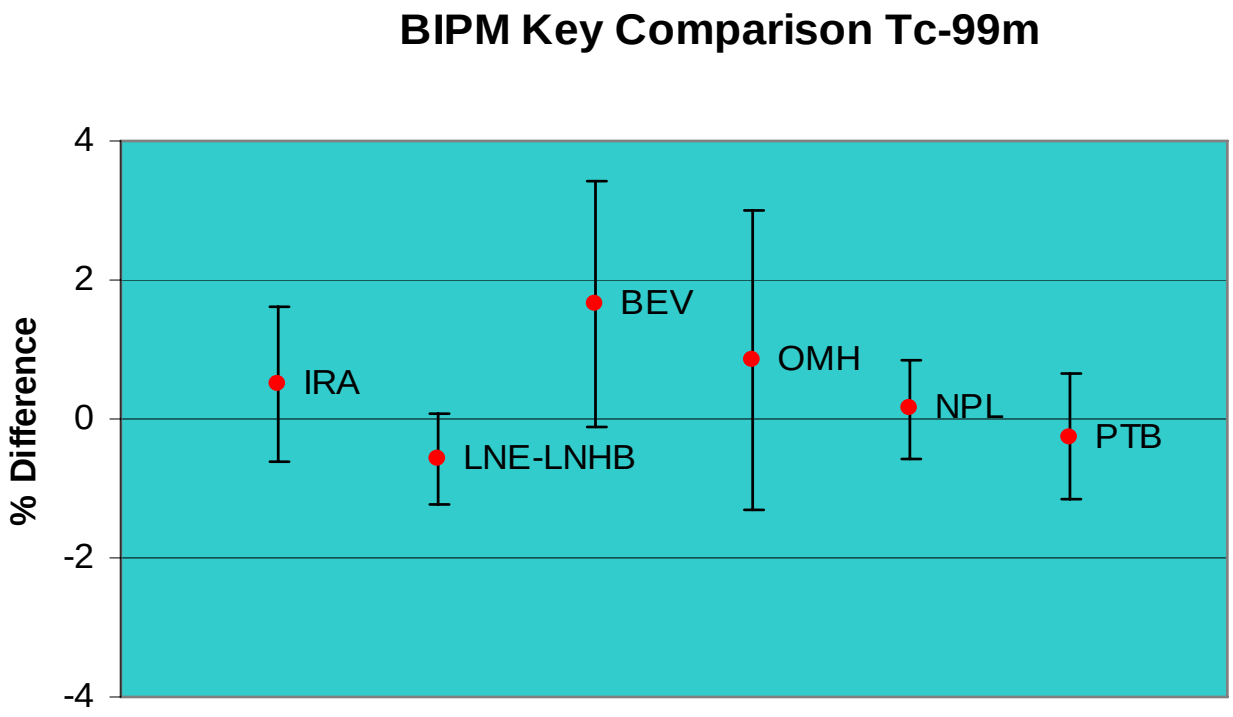

Figure 1: BIPM Key Comparison Results for $^{99}Tc^{m}$

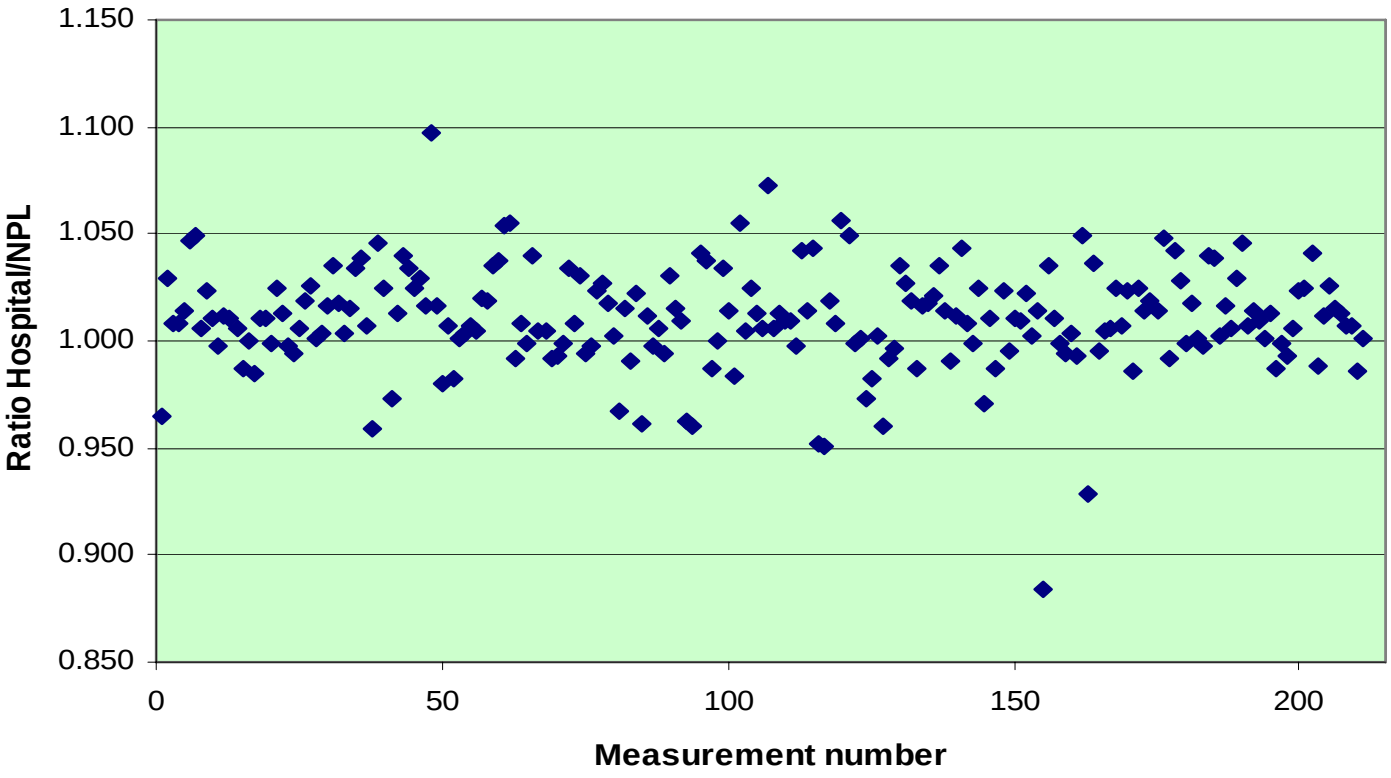

Figure 2: All Results

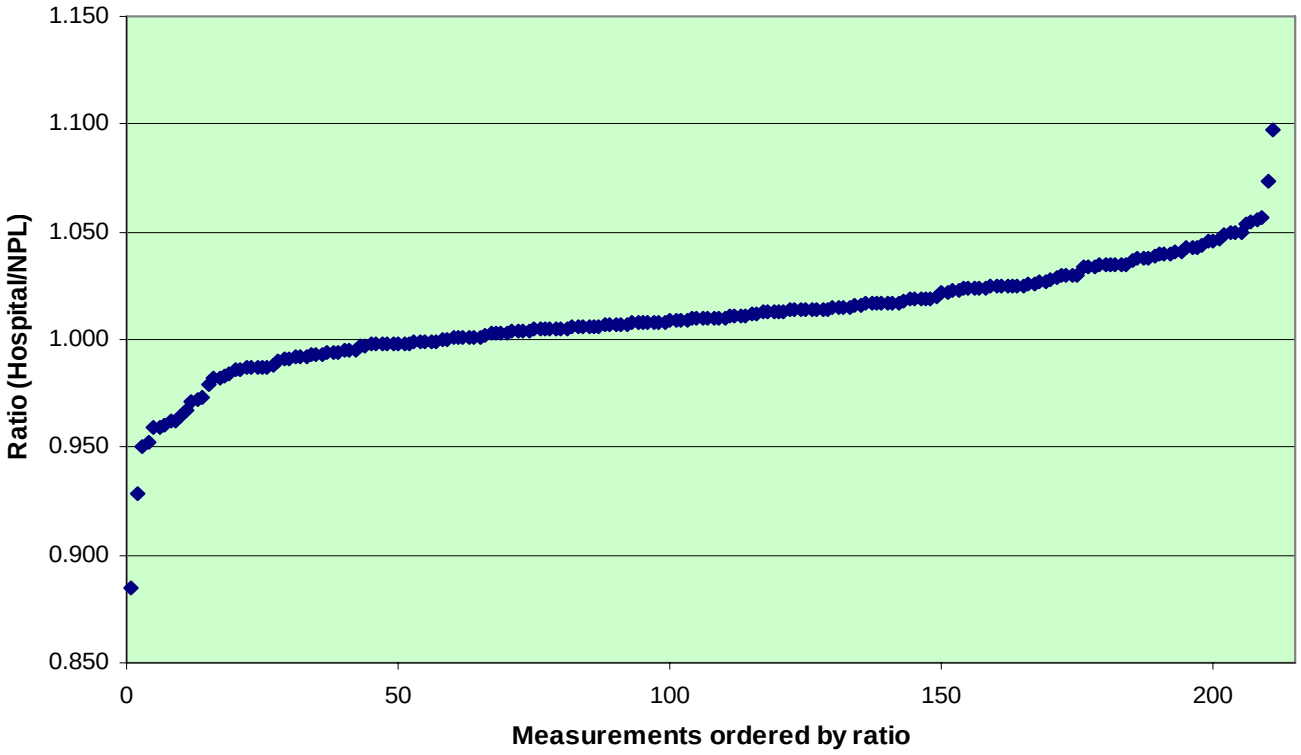

Figure 3: All Results ordered by Ratio (Hospital/NPL)

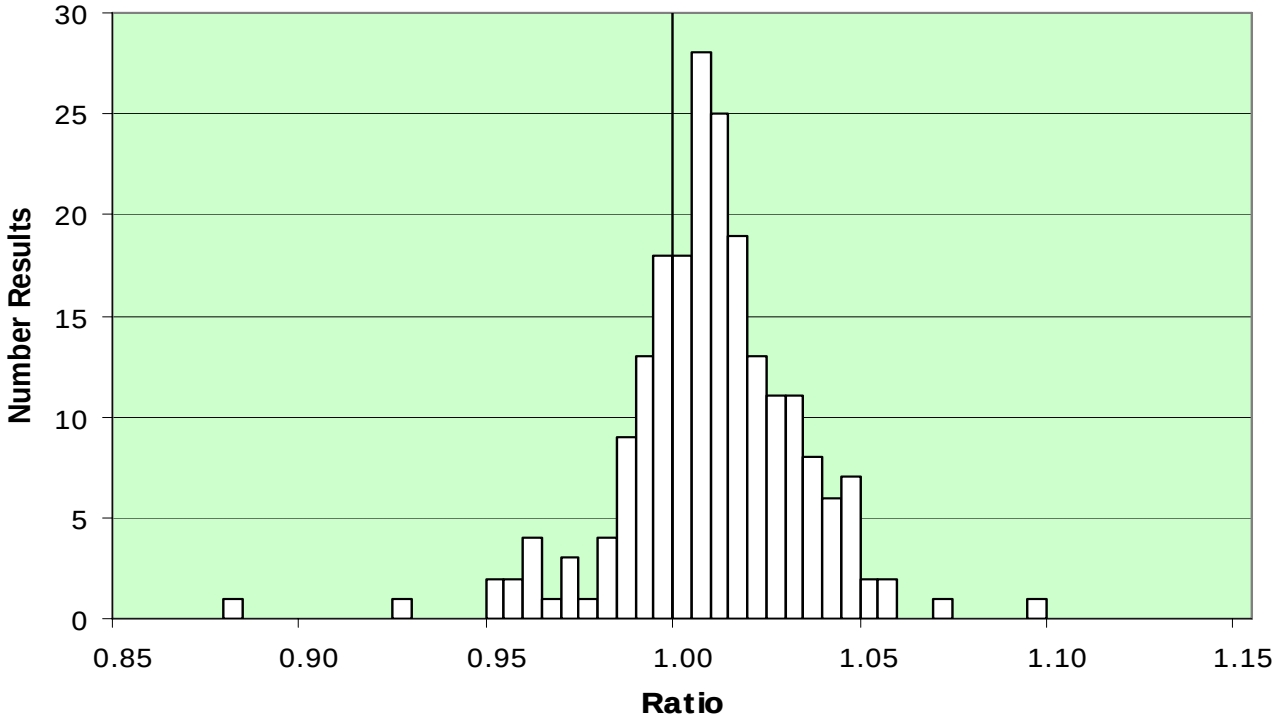

Figure 4: Histogram of Results

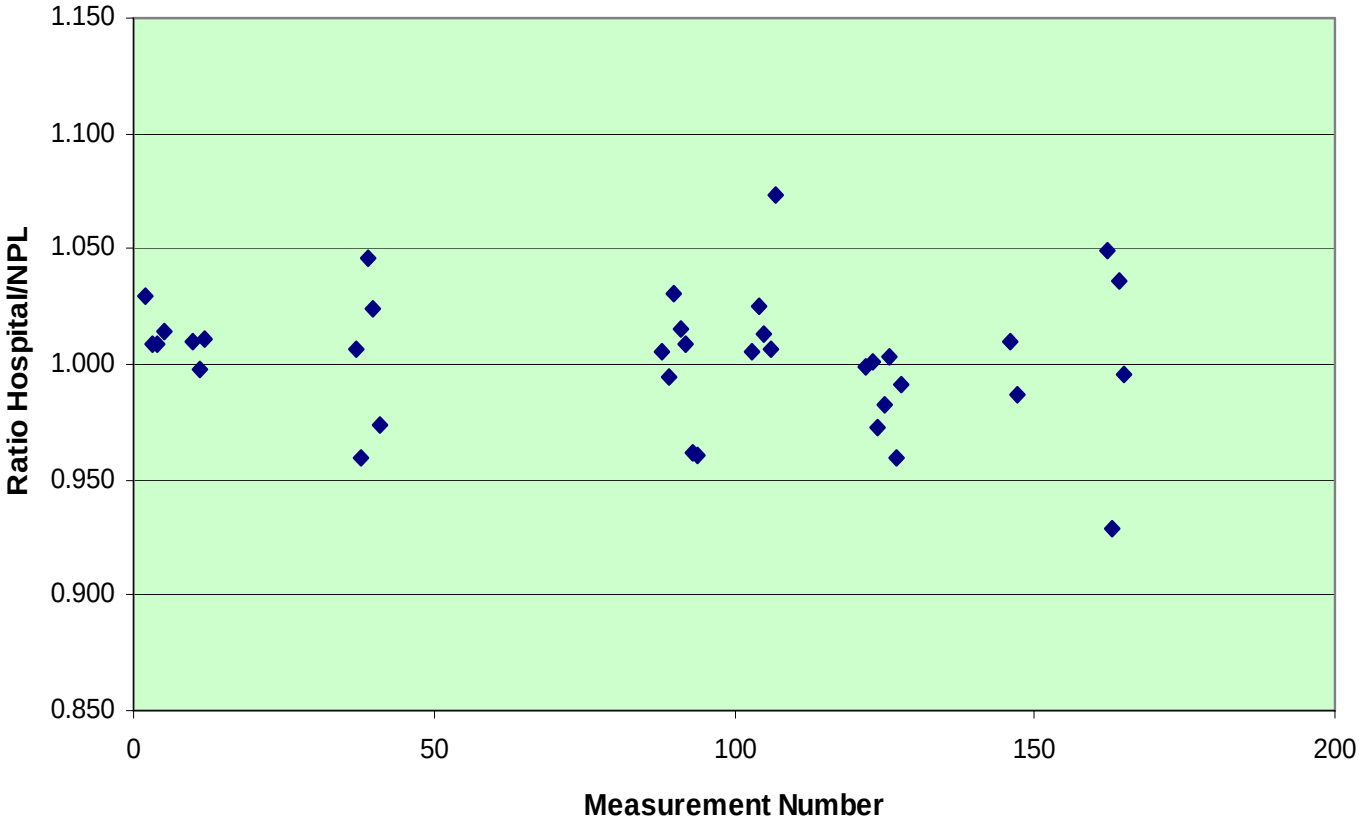

Figure 5: 3rd October results

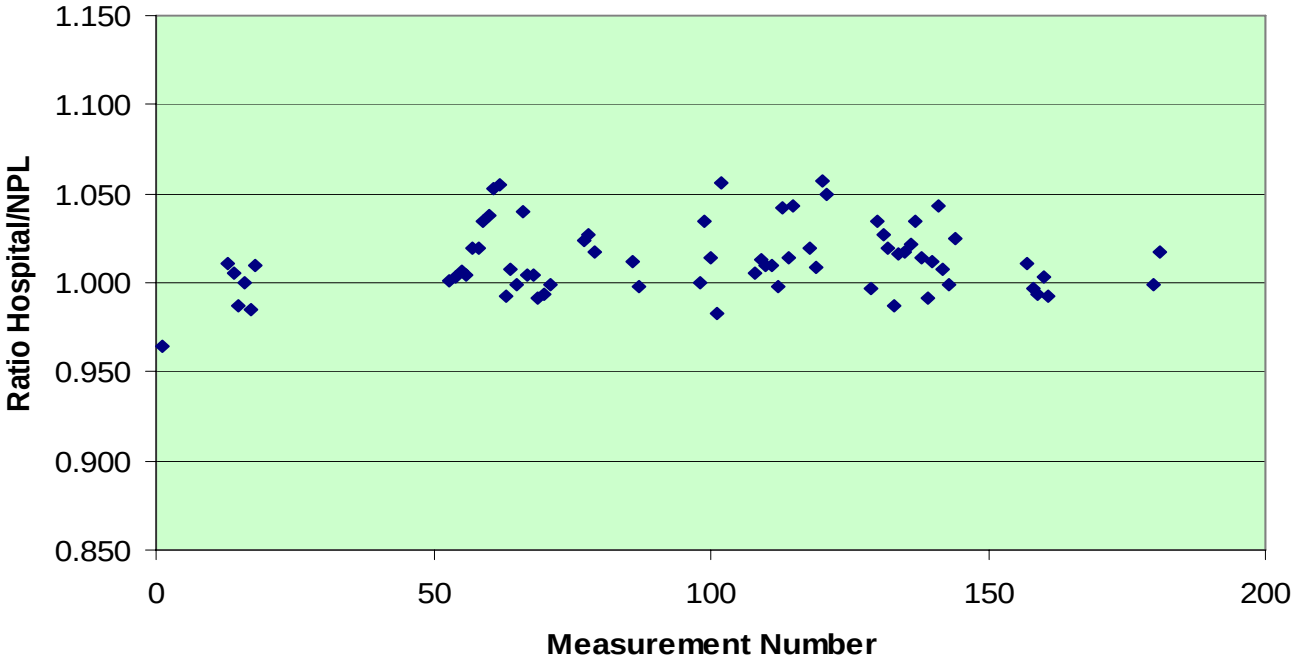

Figure 6: 10th October Results

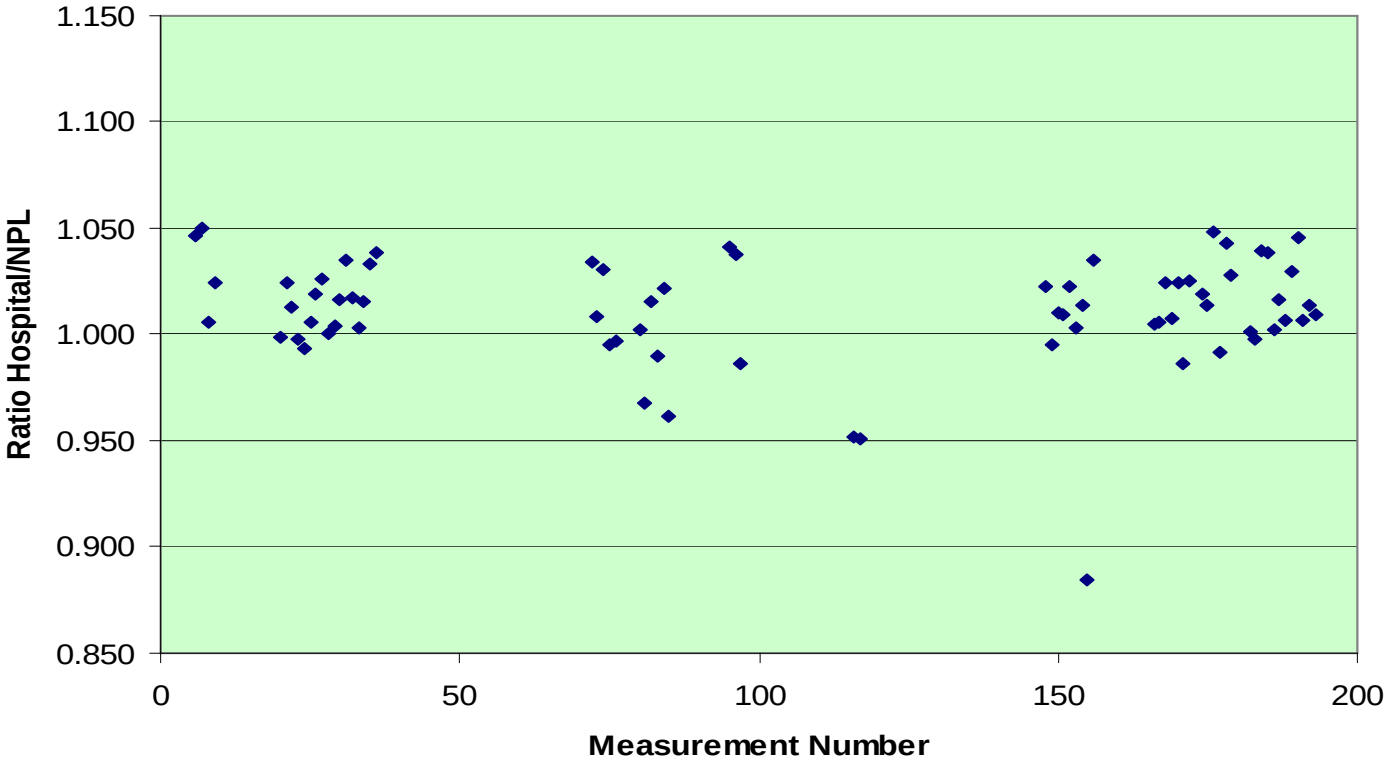

Figure 7: 17th October Results

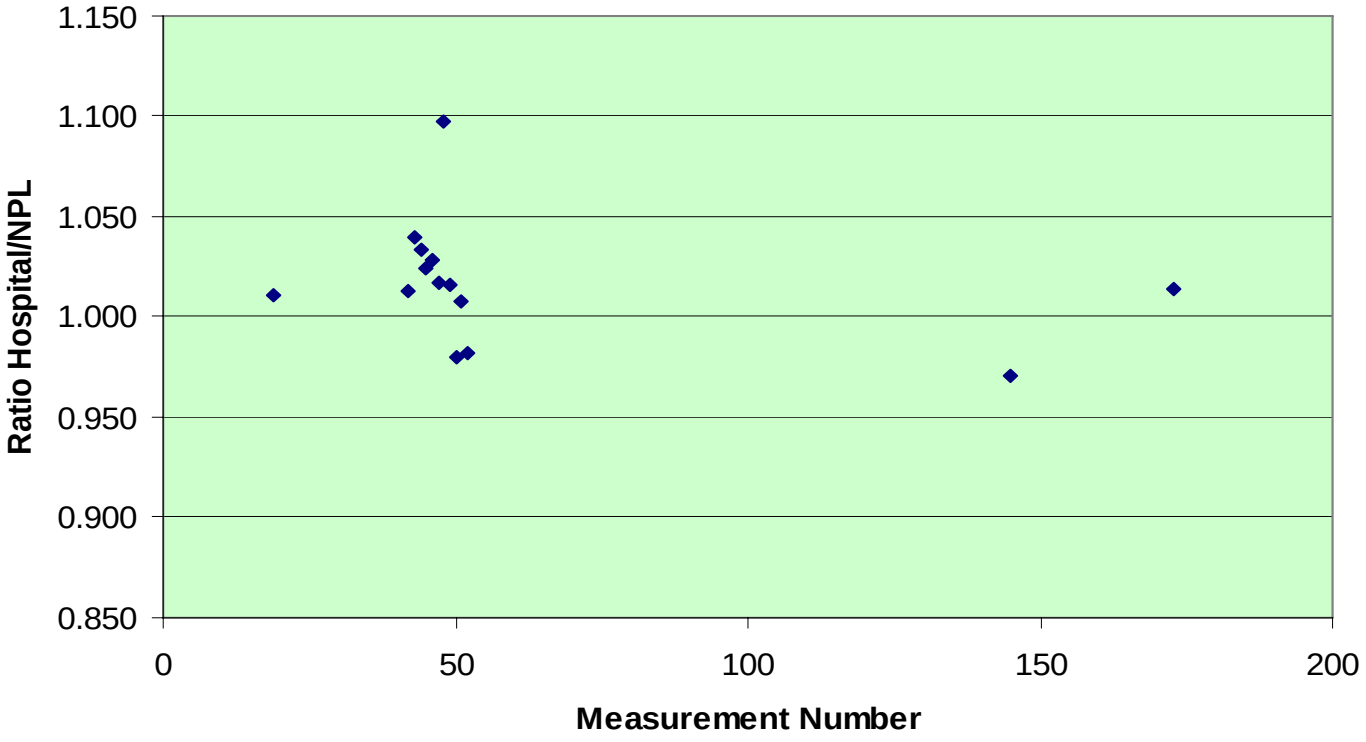

Figure 8: 19th October Results

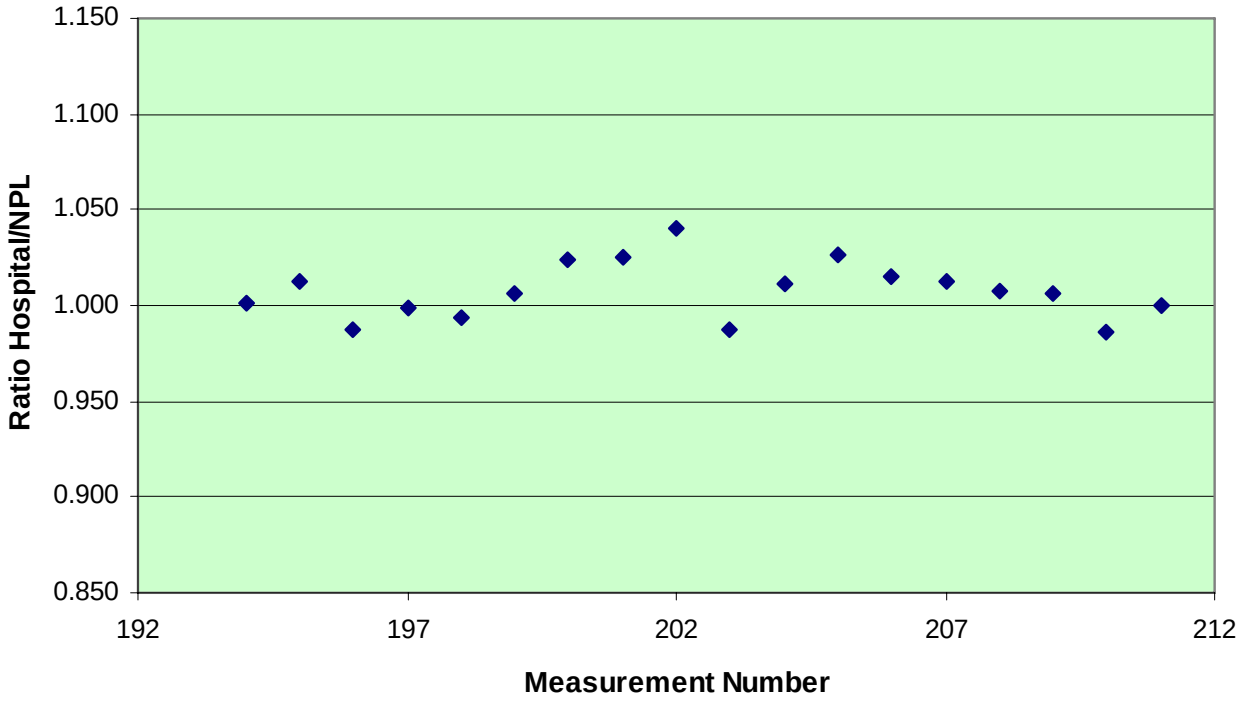

Figure 9: 4th December Results

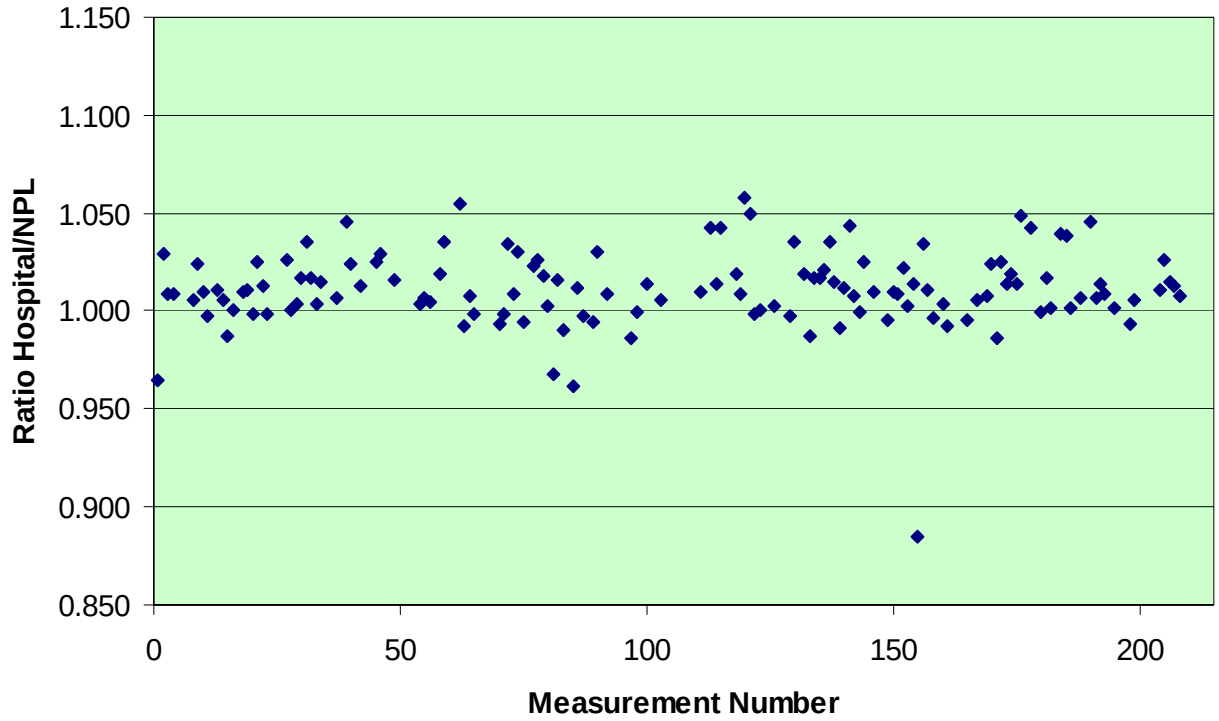

Figure 10: Capintec CRC-15R Results

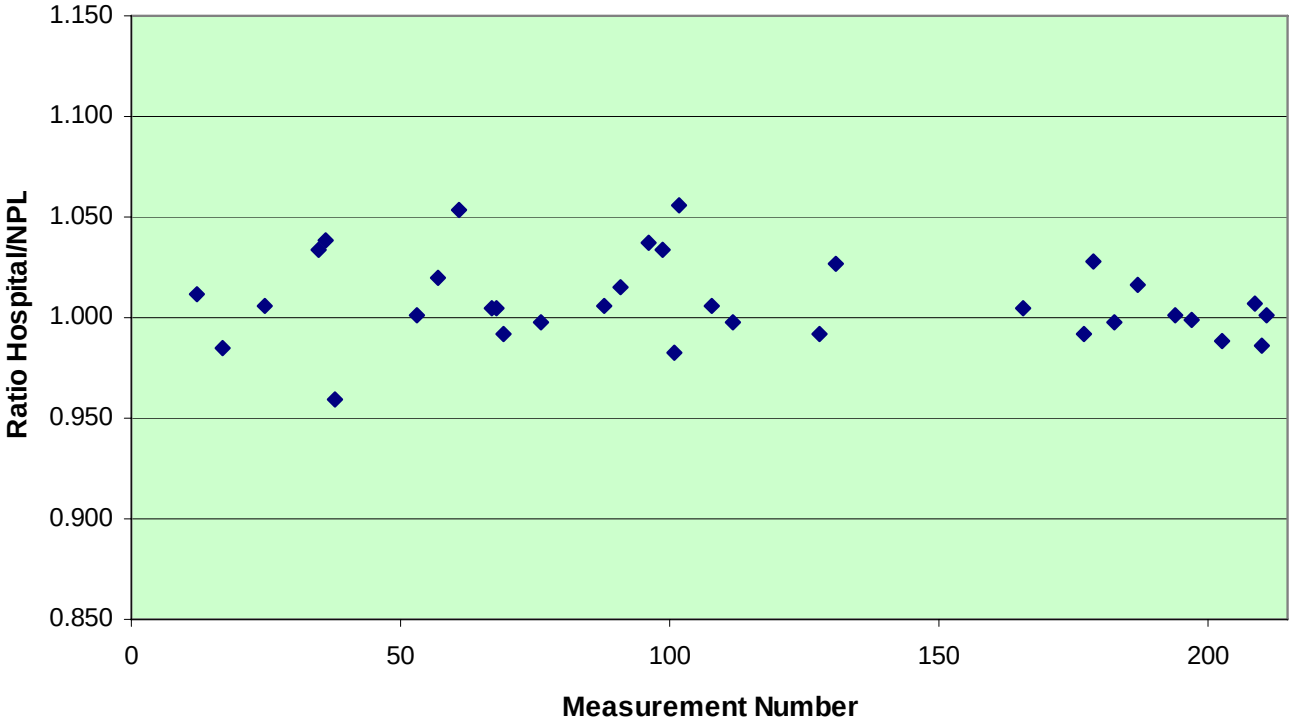

Figure 11: Other Capintec Results

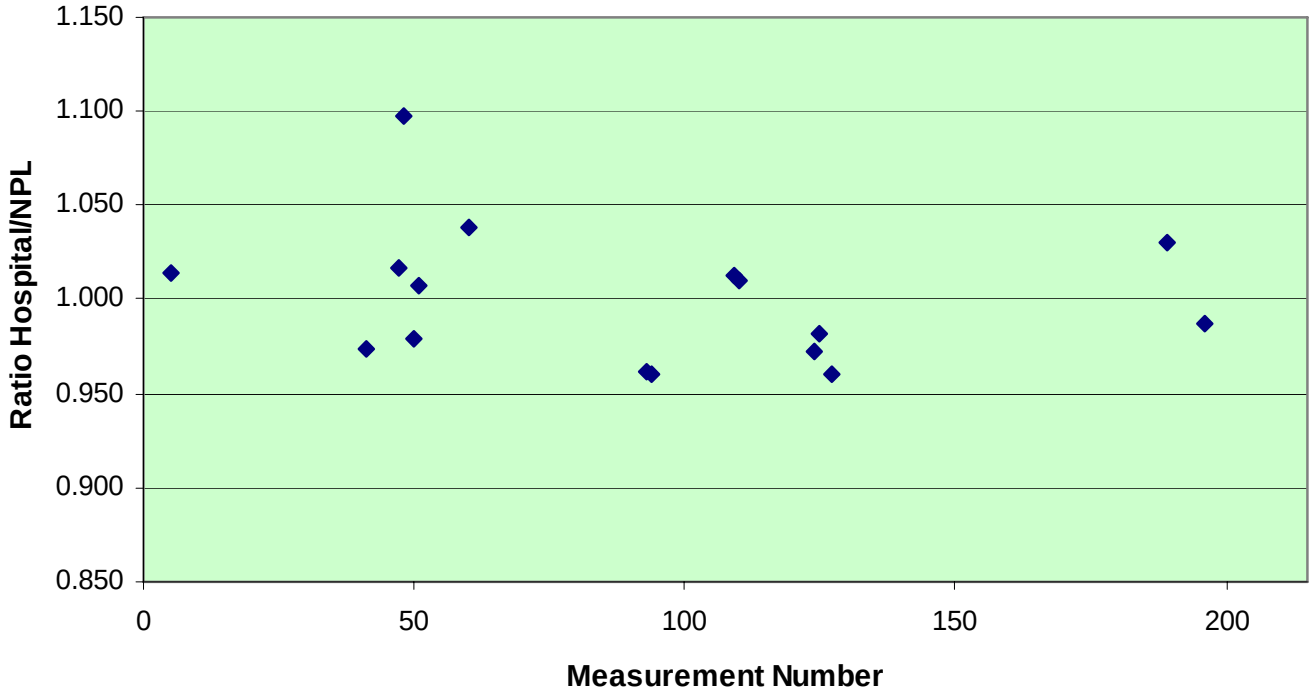

Figure 12: Vinten Results

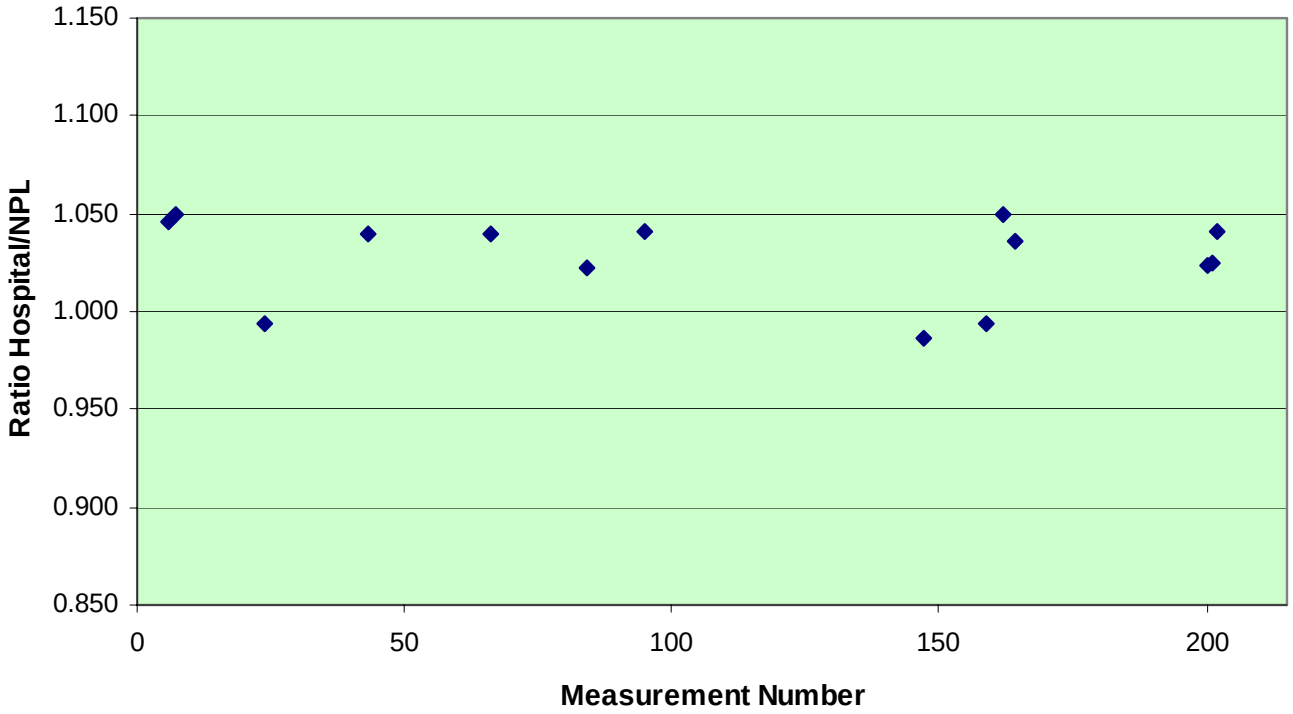

Figure 13: Veenstra Results

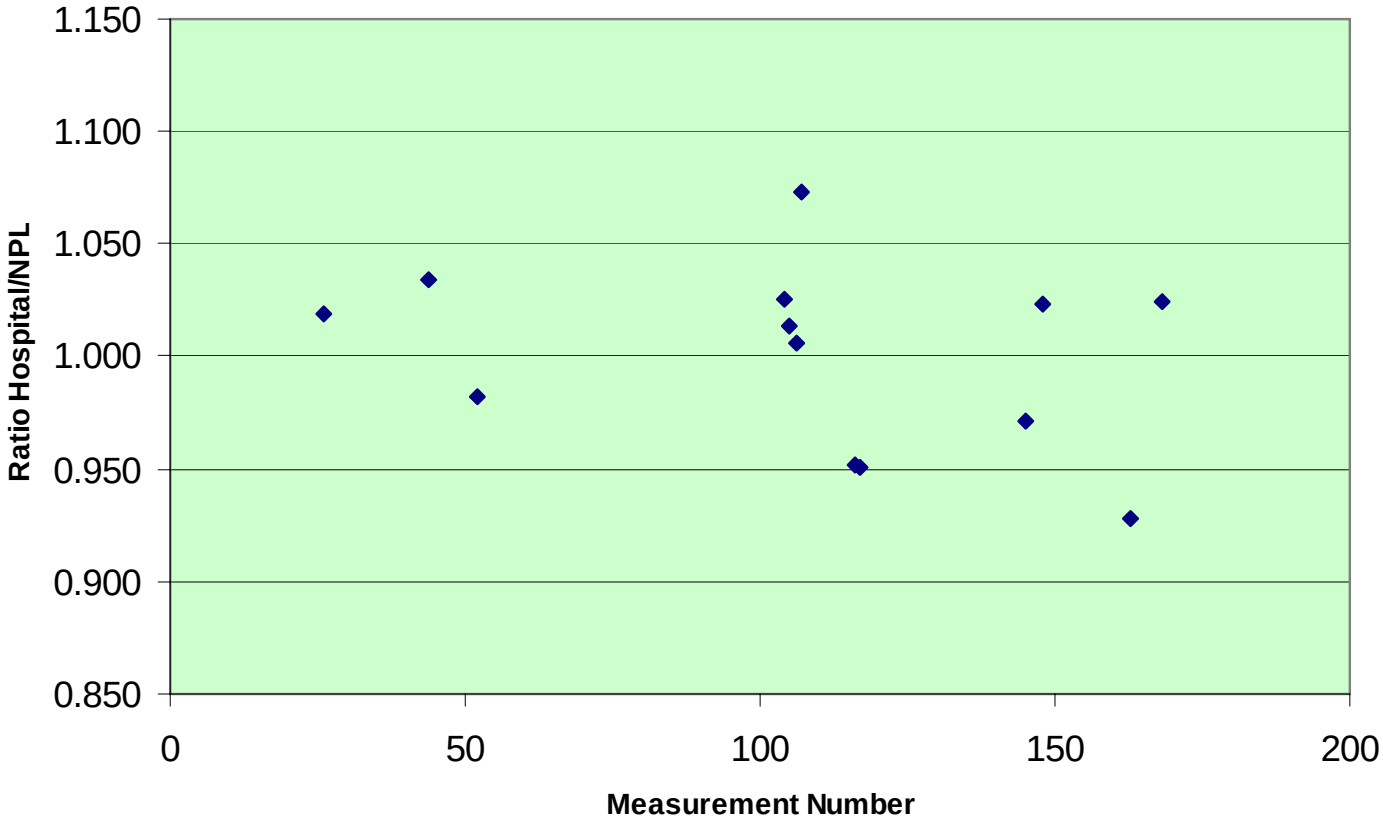

Figure 14: Other Calibrator Results

Table 1 Results
(note that all activities are at noon GMT on day of hospital measurement)

Measure-ment Number	Instrument Manufacturer	Model	Calibration Factor	Hospital Activity MBq	Uncertainty	NPL Activity MBq	Ratio Hospital/ NPL	E_n Values
1	Capintec	CRC 15R	93	23.636		24.51	0.964	
2	Capintec	CRC 15R	79	33.971		33.0	1.029	
3	Capintec	CRC 15R	80	33.275		33.0	1.008	
4	Capintec	CRC 15R	80	33.286	0.3%	33.0	1.009	0.5
5	Vinten	270	2/01434	33.470	0.3%	33.0	1.014	0.8
6	Veenstra	VDC-505	236	31.498	3.0%	30.1	1.046	0.7
7	Veenstra	VDC-505	236	31.597	3.0%	30.1	1.050	0.8
8	Capintec	CRC 15R	80	30.262	3.0%	30.1	1.005	0.1
9	Capintec	CRC 15R	80	30.822	3.0%	30.1	1.024	0.4
10	Capintec	CRC 15R	80	33.234		32.9	1.010	
11	Capintec	CRC 15R	90	32.828		32.9	0.998	
12	Capintec	NPL-CRC	1.227 pA/MBq	33.267		32.9	1.011	
13	Capintec	CRC 15R	80	24.659		24.39	1.011	
14	Capintec	CRC 15R	80	24.521		24.39	1.005	
15	Capintec	CRC 15R	80	24.077		24.39	0.987	
16	Capintec	CRC 15R	80	24.400		24.39	1.000	
17	Capintec	ARC 120R	80	24.112		24.49	0.985	
18	Capintec	CRC 15R	87	24.738		24.49	1.010	
19	Capintec	CRC 15R	80	57.811	0.1%	57.2	1.011	0.6
20	Capintec	CRC 15R	82	29.948	0.1 MBq	30.0	0.998	-0.1
21	Capintec	CRC 15R	80	30.739	0.1 MBq	30.0	1.025	1.3
22	Capintec	CRC 15	80	30.291	3.0%	29.9	1.013	0.2
23	Capintec	CRC 15	80	29.841	3.0%	29.9	0.998	0.0
24	Veenstra	VDC 404	236	29.712	3.0%	29.9	0.994	-0.1
25	Capintec	CRC15 beta	80	30.076	3.0%	29.9	1.006	0.1
26	Atomlab	100	Tc-99m	30.465	3.0%	29.9	1.019	0.3
27	Capintec	CRC 15		30.681	3.0%	29.9	1.026	0.4
28	Capintec	CRC 15R	80	29.926	3.0%	29.9	1.001	0.0
29	Capintec	CRC 15R	Tc-99m	27.154		27.05	1.004	
30	Capintec	CRC 15R		27.500		27.05	1.017	
31	Capintec	CRC 15R		27.995		27.05	1.035	
32	Capintec	CRC 15R		27.512		27.05	1.017	
33	Capintec	CRC 15R		27.133		27.05	1.003	
34	Capintec	CRC 15R		27.461		27.05	1.015	
35	Amersham	ARC 120	70	27.959		27.05	1.034	
36	Amersham	ARC 120	Tc-99m	28.092		27.05	1.039	
37	Capintec	CRC 15R	80	33.329	0.2%	33.1	1.007	0.4
38	Capintec	CRC 12R	80	31.746	0.27%	33.1	0.959	-2.2
39	Capintec	CRC 15R	Tc-99m	34.610	0.17%	33.1	1.046	2.5
40	Capintec	CRC 15R	Tc-99m	33.911	0.17%	33.1	1.025	1.3
41	Vinten	Isocal II	1004	32.220	0.13%	33.1	0.973	-1.5
42	Capintec	CRC 15R	80	57.740	3.0%	57.0	1.013	0.2
43	Veenstra	VDC 404	236	59.264	3.0%	57.0	1.040	0.6
44	NE Tech	Isocal 3	368	58.921	3.0%	57.0	1.034	0.5
45	Capintec	CRC 15R	80	58.403	3.0%	57.0	1.025	0.4
46	Capintec	CRC 15R	80	58.637	3.0%	57.0	1.029	0.4
47	Vinten	Isocal 3	368	57.963	3.0%	57.0	1.017	0.3
48	Vinten	Isocal 3	368	62.559	3.0%	57.0	1.098	1.4

Measure-ment Number	Instrument Manufacturer	Model	Calibration Factor	Hospital Activity MBq	Uncertainty	NPL Activity MBq	Ratio Hospital/ NPL	E_n Values
49	Capintec	CRC 15R	80	57.919	3.0%	57.0	1.016	0.3
50	Vinten	Isocal 2	1004	55.834	5.0%	57.0	0.980	-0.2
51	Vinten	Isocal 2	1004	57.429	5.0%	57.0	1.008	0.1
52	Atomlab	100 +	Tc-99m	55.973	3.0%	57.0	0.982	-0.3
53	Capintec	CRC 15 beta	80	24.512	0.03MBq	24.48	1.001	0.1
54	Capintec	CRC 15R	80	24.567	0.04MBq	24.48	1.004	0.2
55	Capintec	CRC 15R	88	24.650	0.06MBq	24.48	1.007	0.4
56	Capintec	CRC 15R	80	24.584	0.05MBq	24.48	1.004	0.2
57	Capintec	CRC 120R	80	24.967		24.48	1.020	
58	Capintec	CRC 15R	80	24.945	0.11MBq	24.48	1.019	0.9
59	Capintec	CRC 15R	80	25.333	0.02MBq	24.48	1.035	1.9
60	Vinten	671	368	25.491	0.1%	24.56	1.038	2.1
61	Capintec	NPL/CRC	1.227 pA/MBq	25.870	0.2%	24.56	1.053	2.9
62	Capintec	CRC 15R	80	25.888	6.2%	24.54	1.055	0.4
63	Capintec	CRC 15R	80	24.344	6.2%	24.54	0.992	-0.1
64	Capintec	CRC 15R	80	24.737	6.2%	24.54	1.008	0.1
65	Capintec	CRC 15R	80	24.503	6.2%	24.54	0.998	0.0
66	Veenstra	VDC-505	236	25.510	6.2%	24.54	1.040	0.3
67	Capintec	ARC 120	80	24.655	7.6%	24.54	1.005	0.0
68	Capintec	ARC 120	Tc-99m	24.659	7.6%	24.54	1.005	0.0
69	Capintec	ARC 120	80	24.334	7.6%	24.54	0.992	-0.1
70	Capintec	CRC 15R	80	24.380	6.2%	24.54	0.993	-0.1
71	Capintec	CRC 15R	80	24.503	4.0%	24.54	0.999	0.0
72	Capintec	CRC 15R	Tc-99m	31.034	0.16%	30.0	1.034	1.9
73	Capintec	CRC 15R	Tc-99m	30.253	0.26%	30.0	1.008	0.5
74	Capintec	CRC 15R	Tc-99m	30.908	0.22%	30.0	1.030	1.6
75	Capintec	CRC 15R	Tc-99m	29.841	0.16%	30.0	0.995	-0.3
76	Capintec	CRC 12	Tc-99m	29.918	0.20%	30.0	0.997	-0.1
77	Capintec	CRC 15R	80	25.106	3.6%	24.53	1.023	0.3
78	Capintec	CRC 15R	80	25.180	3.6%	24.53	1.027	0.3
79	Capintec	CRC 15R		24.962	3.6%	24.53	1.018	0.2
80	Capintec	CRC 15R	Tc-99m	30.075	1.5%	30.0	1.003	0.1
81	Capintec	CRC 15R	85	28.922	0.2%	29.9	0.967	-1.8
82	Capintec	CRC 15R	82	30.367	0.2%	29.9	1.016	0.8
83	Capintec	CRC 15R	83	29.607	0.2%	29.9	0.990	-0.5
84	Veenstra	VDC 404	236	30.553	0.1%	29.9	1.022	1.2
85	Capintec	CRC 15R	93	28.761	0.25%	29.9	0.962	-2.0
86	Capintec	CRC 15R	80	24.849	4.1%	24.55	1.012	0.1
87	Capintec	CRC 15R	80	24.490	4.1%	24.55	0.998	0.0
88	Capintec	ARC 120	80	33.080	0.3%	32.9	1.005	0.3
89	Capintec	CRC 15R	80	32.711	0.2%	32.9	0.994	-0.3
90	Capintec	CRC 15R	80	33.893	0.2%	32.9	1.030	1.6
91	Capintec	15W	80	33.293	0.2%	32.8	1.015	0.8
92	Capintec	15R	80	33.092	0.3%	32.8	1.009	0.5
93	Vinten	Isocal II	1004	31.557	0.5%	32.8	0.962	-1.9
94	Vinten	Isocal II	1004	31.511	0.1%	32.8	0.961	-2.2
95	Veenstra	VDC 505	Tc-99m	31.232	7%	30.0	1.041	0.3
96	Capintec	CRC 120R	Tc-99m	31.126	17%	30.0	1.038	0.1
97	Capintec	CRC 15R	Tc-99m	29.599	3.0%	30.0	0.987	-0.2
98	Capintec	CRC 15R	90	24.488		24.49	1.000	
99	Capintec	ARC 120R	80	25.328		24.49	1.034	
100	Capintec	CRC 15R	80	24.840		24.49	1.014	

Measure-ment Number	Instrument Manufacturer	Model	Calibration Factor	Hospital Activity MBq	Uncertainty	NPL Activity MBq	Ratio Hospital/ NPL	E_n Values
101	Capintec	CRC 10R	80	24.076		24.49	0.983	
102	Capintec	CRC 10R	80	25.852		24.49	1.056	
103	Capintec	CRC 15R	Tc-99m	33.069		32.9	1.005	
104	Biodex	Atomlab 100	Tc-99m	33.729	3%	32.9	1.025	0.4
105	Biodex	Atomlab 100	Tc-99m	33.342	3%	32.9	1.013	0.2
106	Siel	DCAL 1	Tc-99m	33.108	5%	32.9	1.006	0.1
107	Siel	DCAL 1	Tc-99m	35.303	5%	32.9	1.073	0.7
108	Capintec	CRC 15beta	Tc-99m	24.705	0.3%	24.57	1.005	0.3
109	Vinten	Isocal IV	Tc-99m	24.879	0.08%	24.57	1.013	0.7
110	Vinten	Isocal IV	Tc-99m	24.807	1.2%	24.57	1.010	0.3
111	Capintec	CRC 15R	80	24.792	3.4%	24.55	1.010	0.1
112	Capintec	CRC 15beta	80	24.497	3.4%	24.55	0.998	0.0
113	Capintec	CRC 15R	80	25.594	3.4%	24.55	1.043	0.6
114	Capintec	CRC 15R	80	24.897	3.4%	24.55	1.014	0.2
115	Capintec	CRC 15R	80	25.604	3.4%	24.55	1.043	0.6
116	Biodex	Atomlab200	Tc-99m	28.559	12%	30.0	0.952	-0.2
117	Biodex	Atomlab200	Tc-99m	28.523	12%	30.0	0.951	-0.2
118	Capintec	CRC 15R	80	25.007		24.53	1.019	
119	Capintec	CRC 15R	80	24.751		24.53	1.009	
120	Capintec	CRC 15R	80	25.944		24.53	1.058	
121	Capintec	CRC 15R	80	25.760		24.53	1.050	
122	Capintec	CRC 15R	80	33.049		33.1	0.998	
123	Capintec	CRC 15R	80	33.126		33.1	1.001	
124	Vinten	Isocal II	Tc-99m	32.191		33.1	0.973	
125	Vinten	Isocal II	1004	32.520		33.1	0.982	
126	Capintec	CRC 15R	80	33.191		33.1	1.003	
127	Vinten	Isocal II	1004	31.765		33.1	0.960	
128	Capintec	CRC 15Rbeta	80	32.817		33.1	0.991	
129	Capintec	CRC 15R	80	24.508	3.52%	24.58	0.997	0.0
130	Capintec	CRC 15R	80	25.436	1.84%	24.58	1.035	0.8
131	Capintec	ARC 120	Tc-99m	25.232	2.17%	24.58	1.027	0.6
132	Capintec	CRC 15R	80	25.044	1.38%	24.58	1.019	0.6
133	Capintec	CRC 15R	80	24.264	1.64%	24.58	0.987	-0.3
134	Capintec	CRC 15R	Tc-99m	24.949		24.54	1.017	
135	Capintec	CRC 15R	Tc-99m	24.966		24.54	1.017	
136	Capintec	CRC 15R	Tc-99m	25.067		24.54	1.021	
137	Capintec	CRC 15R	Tc-99m	25.396		24.54	1.035	
138	Capintec	CRC 15R	Tc-99m	24.895		24.54	1.014	
139	Capintec	CRC 15R	Tc-99m	24.323		24.54	0.991	
140	Capintec	CRC 15R	Tc-99m	24.824		24.54	1.012	
141	Capintec	CRC 15R	Tc-99m	25.611		24.54	1.044	
142	Capintec	CRC 15R	Tc-99m	24.733		24.54	1.008	
143	Capintec	CRC 15R	Tc-99m	24.522		24.54	0.999	
144	Capintec	CRC 15R	Tc-99m	25.154		24.54	1.025	
145	Curiementer	PTW	Tc-99m	55.448	3.6%	57.1	0.971	-0.4
146	Capintec	CRC 15R	80	33.333	4.3%	33.0	1.010	0.1
147	Veenstra	VDC 404	236	32.564	3.5%	33.0	0.987	-0.2
148	NE Tech	Isocal IV	Tc-99m	30.686	0.84%	30.0	1.023	0.9
149	Capintec	CRC 15R	Tc-99m	29.859	0.2%	30.0	0.995	-0.3
150	Capintec	CRC 15R	Tc-99m	30.300	0.2%	30.0	1.010	0.5
151	Capintec	CRC 15R	Tc-99m	30.270	0.1%	30.0	1.009	0.5
152	Capintec	CRC 15R	Tc-99m	30.674	0.2%	30.0	1.022	1.2

Measure-ment Number	Instrument Manufacturer	Model	Calibration Factor	Hospital Activity MBq	Uncertainty	NPL Activity MBq	Ratio Hospital/ NPL	E_n Values
153	Capintec	CRC 15R	Tc-99m	30.084	0.3%	30.0	1.003	0.1
154	Capintec	CRC 15R	Tc-99m	30.422	0.2%	30.0	1.014	0.8
155	Capintec	CRC 15R	Tc-99m	26.535	0.3%	30.0	0.885	-6.2
156	Capintec	CRC 15R	Tc-99m	31.041	0.0%	30.0	1.035	1.9
157	Capintec	CRC 15R	80	24.863	3%	24.61	1.010	0.2
158	Capintec	CRC 15R	80	24.582	3%	24.61	0.999	0.0
159	Veenstra	VDC 404	236	24.454	4%	24.61	0.994	-0.1
160	Capintec	CRC 15R	80	24.701	3%	24.61	1.004	0.1
161	Capintec	CRC 15R	80	24.431	3%	24.61	0.993	-0.1
162	Veenstra	VDC 505	236	34.637	0.26%	33.0	1.050	2.6
163	Atomlab	100	35.1	30.638		33.0	0.928	
164	Veenstra	VDC 405	236	34.207	0.13%	33.0	1.037	2.0
165	Capintec	CRC 15R	80	32.849	0.16%	33.0	0.995	-0.3
166	Capintec	ARC 120	80	30.143	0.20%	30.0	1.005	0.3
167	Capintec	CRC 15R	80	30.163	0.21%	30.0	1.005	0.3
168	NE Tech	Isocal IV	368	30.729	0.31%	30.0	1.024	1.3
169	Capintec	CRC 15R	80	30.223	0.32%	30.0	1.007	0.4
170	Capintec	CRC 15R	80	30.718	0.32%	30.0	1.024	1.2
171	Capintec	CRC 15R	80	29.583	0.26%	30.0	0.986	-0.7
172	Capintec	CRC 15R	80	30.746	0.32%	30.0	1.025	1.3
173	Capintec	CRC 15R	80	57.813	2.2%	57.0	1.014	0.3
174	Capintec	CRC 15R	80	30.565	4.0%	30.0	1.019	0.2
175	Capintec	CRC 15R	80	30.424	4.0%	30.0	1.014	0.2
176	Capintec	15R	Tc-99m	31.453		30.0	1.048	
177	Capintec	120R	Tc-99m	29.760		30.0	0.992	
178	Capintec	15R	Tc-99m	31.275		30.0	1.042	
179	Capintec	CRC 120	Tc-99m	30.829		30.0	1.028	
180	Capintec	CRC 15R	80	22.011	4.1%	22.03	0.999	0.0
181	Capintec	CRC 15R	80	22.409	4.1%	22.03	1.017	0.2
182	Capintec	CRC 15R	Tc-99m	30.033	0.20%	30.0	1.001	0.1
183	Capintec	ARC 120	Tc-99m	29.935	0.6%	30.0	0.998	-0.1
184	Capintec	CRC 15R	Tc-99m	31.187	0.2%	30.0	1.040	2.1
185	Capintec	CRC 15R	Tc-99m	31.143	0.2%	30.0	1.038	2.1
186	Capintec	CRC 15R	Tc-99m	30.058	0.3%	30.0	1.002	0.1
187	Capintec	CRC 7B	Tc-99m	30.504	0.2%	30.0	1.017	0.9
188	Capintec	CRC 15R	Tc-99m	30.188	0.2%	30.0	1.006	0.3
189	Vinten	Isocal III	Tc-99m	30.894	0.9%	30.0	1.030	1.2
190	Capintec	CRC 15R	Tc-99m	31.363	0.2%	30.0	1.045	2.5
191	Capintec	CRC 15R	80	30.311	4.3%	30.1	1.007	0.1
192	Capintec	CRC 15R	80	30.518	4.1%	30.1	1.014	0.2
193	Capintec	CRC 15R	80	30.375	3.6%	30.1	1.009	0.1
194	Capintec	CRC 15 PET	90	630.2		629.5	1.001	
195	Capintec	CRC 15R	80	637.8		629.5	1.013	
196	Vinten	Isocal 2	1004	621.5		629.5	0.987	
197	Capintec	CRC 10B	80	629.0		629.5	0.999	
198	Capintec	CRC 15R	80	625.3		629.5	0.993	
199	Capintec	CRC 15R	80	633.1		629.5	1.006	
200	Veenstra	VDC	236	644.2		629.5	1.023	
201	Veenstra	VDC	236	645.3		629.5	1.025	
202	Veenstra	VDC-405	236	655.1		629.5	1.041	
203	Capintec	ARC 120R	80	621.9		629.5	0.988	
204	Capintec	CRC 15R	80	636.6		629.5	1.011	

Measure-ment Number	Instrument Manufacturer	Model	Calibration Factor	Hospital Activity MBq	Uncertainty	NPL Activity MBq	Ratio Hospital/ NPL	E_n Values
205	Capintec	CRC 15R	80	646.0		629.5	1.026	
206	Capintec	CRC 15R	80	639.0		629.5	1.015	
207	Capintec	CRC 15R	80	637.3		629.5	1.012	
208	Capintec	CRC 15R	80	634.2		629.5	1.007	
209	Capintec	CRC 10RB	80	633.7		629.5	1.007	
210	Capintec	CRC 12	80	620.7		629.5	0.986	
211	Capintec	ARC 120R	80	629.9		629.5	1.001	

Table 2 Results by subset

Subset	**Figure**	**Number of Measurements**	**Mean Ratio Hospital/NPL**	**Standard Deviation**
All Results	1, 2, 3	211	1.010	2.4%
3rd October	4	37	1.003	2.8%
10th October	5	71	1.013	1.9%
17th October	6	71	1.011	2.6%
19th October	7	14	1.017	3.1%
4th December	8	18	1.008	1.5%
Capintec CRC 15R	9	134	1.011	2.0%
Other Capintec	10	34	1.008	2.1%
Vinten	11	16	1.000	3.6%
Veenstra	12	14	1.028	2.2%
Other Calibrators	13	13	1.000	4.1%
Capintec dial setting 80 or ^{99m}Tc		153	1.011	2.0%
Capintec other dial Settings		15	1.003	2.6%

APPENDIX 1

List of participants.

Participant	Hospital
M. Aldridge	University College London Hospital
S. Anderson	Mount Vernon Hospital, Northwood
I. Belton	Cumberland Infirmary, Carlisle
S. Betts	Norfolk & Norwich University Hospital, Norwich
S. Brown	Southend Hospital, Westcliff-on-Sea
M. Burniston	St. James's University Hospital, Leeds
K. Cockburn	Castle Hill Hospital, Cottingham
R. Cranage	Royal Cornwall Hospital, Truro
J. Cullis	University Hospital Walsgrave, Coventry
N. Dudley	City Hospital Campus, Nottingham
M. Federspiel	Western Infirmary, Glasgow
A. Fletcher	Falkirk & District Royal Infirmary/ Stirling Royal Infirmary
B. Gilmore	Belfast City Hospital
C.H. Green	Northwick Park Hospital, Harrow
M. Greenhow	Wycombe Hospital, High Wycombe
A. Hallam	Churchill Hospital, Oxford
A. Harris	Royal Hallamshire Hospital, Sheffield
P. Hay	Queen's Medical Centre, Nottingham
P. Hinton	Royal Surrey County Hospital, Guildford
S. Hoffmann	Southampton General Hospital
P. Howells	Scarborough Hospital
D. Ibbett	Derbyshire Royal Infirmary, Derby
D. Jones	Rotherham General Hospital
I. Jones	Derriford Hospital, Plymouth
J. Jones	The Royal Free Hospital, London
J. Kerry	Lincoln County Hospital
J. MacDonald	Glan Clwyd Hospital, Bodelwyddan
F. McKiddie	Aberdeen Royal Infirmary, Aberdeen
D. Marshall	Medway Maritime Hospital, Gillingham
D. Monk	Leicester Royal Infirmary
M. Newell	The Royal London Hospital
A. O'Brien	Raigmore Hospital, Inverness
P.J. O'Sullivan	Royal Berkshire Hospital, Reading
B. Parker	Chesterfield Royal Hospital
D.R. Parry-Jones	Addenbrookes Hospital, Cambridge
B. Pratt	Royal Marsden Hospital, Sutton, Surrey
J. Reyes-Goddard	Gloucestershire Royal Hospital, Gloucester

J. Rotherham	Stoke Mandeville Hospital, Aylesbury
J. Segerman	Royal Sussex County Hospital
H. Stockdale	Royal Liverpool University Hospital
A. Tarbuck	University Hospital of North Staffordshire, Stoke-on-Trent
P. Thompson	Doncaster Royal Infirmary
J. Tipping	Christie Hospital, Manchester
B. Ward	Royal Devon & Exeter Hospital, Exeter
H. Weatherburn	Parkside Oncology Clinic, Wimbledon
D. White	Barnsley Hospital
M. Wisbey	Maidstone Hospital

APPENDIX 2

^{99m}Tc Measurement Comparison in UK Hospitals, October 2006

REPORTING FORM

Organisation .....**Participant**.....…...

Address…….....……...….....

.....….....…….....….....…...

.....……...

E-mail .....……

Telephone …….

Fax …….

SAMPLES DETAILS:

Vial identifier: .....……..….

Container type: 10R Schott vial

DETAILS OF RADIONUCLIDE CALIBRATOR:
(If more than one calibrator is used, please photocopy this reporting form and use a separate form for each calibrator):

Manufacturer: …….

Model/Type: ……

Serial No:……..…….

NPL RECOMMENDED HALF-LIVES*: (Please use these half-lives for any required decay corrections)*

^{99m}Tc:	6.0067 hours ± 0.0010 hours (at k=1)
^{99}Mo:	2.7479 days ± 0.0006 days (at k=1)

^{99m}Tc ACTIVITY MEASUREMENTS:

^{99m}Tc Calibration factor/dial setting used: ……..……..……...

Please give details of the origin of dial/preset factor (eg: users' manual, self-derived, etc)

Date and time of measurement (GMT):

Month …...…...… Day ....……...… Hour ...……...… Min ....……...…

Measured background: ……..……. MBq

^{99m}Tc displayed activity: ……..…… MBq
(uncorrected, before background subtraction)

^{99m}Tc activity (after background. subtraction and any correction applied for ^{99}Mo):

.....……... MBq

Please give details of any correction applied to account for ^{99}Mo impurity:

If individual impurity checks are performed routinely, please specify method:

UNCERTAINTIES:

Please provide an estimate of the uncertainty (at k = 1) on your measurements:

Random (Type A): ± .....…….....%

Non-random (Type B): ± ....…….....%

Overall: ± .....…….....%

It would be useful if you could indicate below how these values were estimated.

ADDITIONAL COMMENTS:

Please return this form to:
By 25th October

Desmond MacMahon
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National Physical Laboratory
Teddington, Middlesex, TW11 0LW
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Fax: 020 8943 8700
E-mail: desmond.macmahon@npl.co.uk