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Intercomparison of ^{123}I Solution Sources in UK Hospitals, 2000

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ABSTRACT

Following concerns expressed within the nuclear medicine field about the accuracy of measurements of ^{123}I using radionuclide calibrators, an intercomparison was conducted in 1996 for this particular radionuclide. That exercise highlighted the fact that small variations in wall thickness of either the sample container or the calibrator could generate large variations in response for typical radionuclide calibrators, due to the significant quantity of low energy photons emitted from ^{123}I.

To assess whether the level of measurement performance for ^{123}I has improved as a result of the recommendations made in the previous intercomparison report, a repeat intercomparison exercise was conducted between the National Physical Laboratory (NPL), AEA Technology plc (AEA), Nycomed-Amersham (NA) and the UK hospital physics community.

A total of 318 results were reported for this exercise, of which only about 50 % were within the accepted limit of ± 10 % from the true value. A tendency to underestimate the activity for measurements made in the P6 vials and a significant high bias for syringe results were revealed. Possible sources of errors that explained the inaccuracy of the reported values were also identified.

The exercise has revealed that the accuracy of ^{123}I measurements in the UK hospitals has not improved significantly since the last intercomparison.

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1. INTRODUCTION

A wide variety of radioactive materials is used in UK hospitals for therapy, diagnosis or research purposes. The choice of material depends on the type of the radiation emitted and on its expected pathway through the body. To ensure that these radionuclides are used in the optimum manner, their activity should be accurately determined prior to their administration to a patient. Radionuclide calibrators are the instruments commonly used for this purpose. Their principle of operation is relatively simple and, used correctly via a quality assurance system, they can ensure the desired accuracy of the administered activities. A protocol for establishing and maintaining such a quality 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 is conducting a series of intercomparisons and workshops concerned with the use of radionuclide calibrators in practice. This continues the very well-subscribed intercomparisons conducted in previous years [2-7]. 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.

Following concerns expressed within the nuclear medicine field about the accuracy of measurements of ^{123}I using radionuclide calibrators, an intercomparison was conducted in 1996 for this particular radionuclide [5]. That exercise highlighted the fact that small variations in wall thickness of either the sample container or the calibrator could generate large variations in response for typical radionuclide calibrators, due to the significant quantity of low energy photons emitted from ^{123}I. The magnitude of these effects on the accuracy of clinical measurements of the activity of ^{123}I was confirmed and recommendations were made to the hospital community to revise the calibration figures for their individual calibrators, for standard containers such as P6 vials and syringes.

To assess whether the level of measurement performance for ^{123}I has improved as a result of the proposals made in the previous intercomparison report, a repeat intercomparison exercise was conducted between the National Physical Laboratory (NPL), AEA Technology plc (AEA), Nycomed-Amersham (NA) and the UK hospital physics community.

2. PARTICIPANTS

Participation was open to all UK hospitals and the exercise was publicised via the contact mailing lists maintained by AEA, NA and NPL.

Several participants took the opportunity to share their samples by circulating them amongst other hospital departments in their region.

A list of the participants is given in Appendix 1.

3. INTERCOMPARISON SAMPLES

Individual samples were supplied by NA from a stock solution of ^{123}I, which was accurately sub-divided into a series of 4 ml aliquots in P6 vials, and dispatched to each participant. Two of these samples were sent to NPL for activity assay. At 12:00 GMT on 10 November 1999, the mean activity concentration of the solution in these two samples, as measured by NPL, was approximately 9.3 MBq g^{-1}. The samples comprised ^{123}I, as an aqueous solution of NaI with a chemistry of 0.1 mg g^{-1} I, 0.2 mg g^{-1} $Na_2S_2O_3$ and 1 mg g^{-1} formaldehyde.

4. NPL MEASUREMENTS OF INTERCOMPARISON SAMPLES

The two solutions in P6 vials sent to NPL were assayed using the NPL secondary standard radionuclide calibrator. This system is a sealed, high pressure, re-entrant ionisation chamber, also known as the 671/271 and the ISOCAL IV. This chamber had been previously calibrated for ^{123}I solutions in such a way that direct traceability was maintained to the absolute standards of ^{123}I using the primary standardisation facilities and techniques available at NPL.

Recent measurements performed at NPL consistently showed variations in response between P6 vials from old and new batches, indicating that there are many variants of these, although it is very difficult to visually distinguish one from another. This effect is evidently greater for radionuclides that emit predominantly low-energy photons, such as ^{123}I.

As a check on the validity of the activity measurements of the ^{123}I solution in the P6 vials received at NPL, the solution was dispensed accurately into 2 ml and 5 ml BS ampoules and re-measured using the NPL secondary standard high pressure, re-entrant ionisation chamber, type TPA MkII. The activity concentration of the transferred solution was about 1.2 % lower than the initial value measured in each P6 vial. This suggested that the vials in which the solution was received may not have been identical to those used for the original calibration and so the existing ^{123}I calibration figures for P6 vial could not be applied in this case. Instead, the activity concentration of the ^{123}I intercomparison solution was based on the measurements made in the ampoules. The effect of variations in wall thickness of the P6 vials on the response of the NPL calibrator is illustrated in Figure 2.

Assay of the vials following transfer of the solution indicated no significant adsorption of activity onto the inner wall of the vials.

The presence of any radioactive impurities in the solution samples was checked by gamma spectrometry. This identified the presence, at reference time, of ^{121}Te, at an activity level of about 0.02 % of the ^{123}I activity level. Because the response factor for the contaminant, for the NPL calibrator, is about 3.5 times higher that that of ^{123}I, the effect of the contaminant was taken into account when determining the ^{123}I activity concentration.

5. INTERNATIONAL EQUIVALENCE OF NPL PRIMARY STANDARDS

As explained in section 4, the measurements on which the results of this exercise were based were made using ionisation chambers which had themselves been calibrated using primary standards of ^{123}I produced at NPL.

The previous ^{123}I intercomparison report [5] described how the accuracy of those primary standards was validated by an international comparison exercise conducted in 1983. A stock solution of ^{123}I was assayed by NPL, the Laboratorie de Metrologie Rayonnements Ionisants (the French equivalent of NPL) - now called Laboratorie National de Henri Becquerel (LNHB) and the Bureau Centrale de Mesures Nucleaires (the European Joint Research Centre in Belgium – now called the Institute for Reference Material and Measurements (IRMM)).
The results from all three metrology institutes agreed to better than 0.5 %. The data from this exercise are presented in Table 1 and Figure 1.

6. CAPINTEC ARC 120 MEASUREMENTS AT NPL

As Capintec type radionuclide calibrators are the most commonly used systems in UK hospitals, the ^{123}I intercomparison solution was also measured on the Capintec ARC 120 model held at NPL. To estimate the container effect for this particular system, the solution was assayed initially in the received P6 vials, then in standard P6 vials, using the recommended Calibration Settings, namely ^{123}I pre-set and 277 dial factor. Both activity values were compared against those obtained from measurements made in the NPL secondary standard system. The results for the received P6 vials were about 4.5 % lower than the true activities, while the assay of solution in standard P6 vials showed an even larger difference, of 9.9 % lower than the true activities. These comparisons, as shown in Figure 3, suggest that the Capintec type calibrators are more sensitive to small variations in the wall thickness of the sample container than the NPL calibrator.

No significant variation in response between the two calibration setting options was noticed.

Measurements made by NPL on this Capintec 120 calibrator in the previous ^{123}I intercomparison exercise indicated that the response of this calibrator for solution samples in various plastic syringes was about 25 % to 60% higher than that for P6 vials.

7. MEASUREMENTS AND REPORTING PROTOCOL

Participants were invited to assay their samples in each of their radionuclide calibrators and to report their results directly to NPL. Subsequently the NA certificates of calibrations were sent to each participant, stating the traceable activity content of their solution sample based on the NPL standardisation.

Participants were encouraged to provide additional information for this exercise by making measurements using both pre-set and dial settings, by transferring their solution sample to other containers routinely used, such as syringes, and reporting their results on these. Estimates of measurement uncertainties were also sought. A standard reporting form was provided.

8. CONFIDENTIALITY

All results were reported directly to NPL. Each result was given a code by NPL, consisting of a number indicating the individual participating hospital or group of hospitals within a NHS Trust and a letter indicating the particular calibrator in that hospital. This code system both preserves the anonymity of individual participants and allows the comparison of results from individual calibrators within a hospital.

9. ANALYSIS OF RESULTS

27 of the 28 possible participants reported a total of 318 results, representing measurements made on 128 calibrators in 33 hospitals. All results have been decayed to the same reference time of 12:00 GMT on 10 November 1999. The half-life of ^{123}I used was 13.2 hours [8].

The activity content of each sample was determined from the activity concentration measurements made by NPL and the masses of solution dispensed by NA. For those samples that were subsequently transferred by the participants to other container types (in most cases syringes), the activities were determined from the participants declared dispensings and the NPL measured activity concentrations. The reported activities of the intercomparison samples and of the transferred solutions were compared to these NPL calculations.

The results have been tabulated as ratios of reported activity to the NPL determined value and are presented in Table 2. An asterisk (*) in the “setting” column of Table 2 indicates that the participant applied a self-determined correction factor or a self-derived dial factor.

None of the participants reported any evidence of contaminant checks. As the effect of the contaminant on the reported results was about 0.07 % at the reference time, when using the NPL calibrator, it was assumed that the effect on other chambers would be of a similar magnitude and hence it was regarded as insignificant in comparison with other possible sources of error.

Summarised breakdowns of the results by container and calibrator type are given in Table 3. In the breakdown by calibrator type, the original vial results and the syringe results were considered separately, while in the summary by container all reported results were included. The results are also selectively displayed in histogram form in Figures 4 to 9.
The reported uncertainties associated with the individual results sent by the participants are listed in Table 4.

10. DISCUSSION

The main aims of this exercise were to assess the accuracy of ^{123}I activity measurements using typical radionuclide calibrators and containers available in UK hospitals, to provide the participants with a traceable standard which enables them to review the existing calibration factors for their systems, for this particular radionuclide, and to determine whether the problems highlighted by the 1996 exercise had been noted and acted upon.

From all the reported results, some of the residue values need to be regarded with some reservation because the estimation of the mass remaining after transfer is not accurate and this could lead to a distortion of the related results. The discussion, as it relates to containers, is confined to those solution results for the P6 vials sent to the participants and for syringes.

10.1. CAPINTEC 120 MEASUREMENT AT NPL

Because previous NPL measurements on Capintec 120 calibrator showed large discrepancies for both P6 vial and syringe activity results, and because these systems are used routinely by a significant number of UK hospitals, it is useful to discuss their performance first.

The User Manual [9] for this calibrator states for the ^{123}I radionuclide that:

a) The Calibration Setting Numbers are given for approximately 5 grams of radioactive solution in a standard source ampoule made of about 0.6 mm thick borosilicate glass. The standard radioactive source in the ampoule is, however, a good approximation for a radiopharmaceutical in a plastic syringe (wall thickness of about 1.2 mm), for most radioisotopes;

b) The correction factor for syringe is 15 %.

Present (for variants of P6 vials) and previous (for syringes) NPL measurements have indicated that the Calibration setting for ^{123}I is valid only for a container which is never used in practice and that the response of this calibrator is more sensitive to the format of measurement and to small variations in the wall thickness of the containers than the NPL calibrator for example. As these effects are larger for radionuclides that emit predominantly low-energy photons, it is clear that these systems should be recalibrated for ^{123}I, in the preferred standard measurement format, and new Calibration Settings derived.

10.2. ALL RESULTS

This intercomparison sought to provide a true reflection of the accuracy of ^{123}I activity measurements in UK hospitals and to identify possible sources of error. The overall received data, displayed in Figure 4, show a wide spread of about ± 50 % from the NPL determined activity. It is generally accepted that hospitals should be able to

determine the activity of a radionuclide prior to administration to within ± 10 % of the true value. The intercomparison data show that only about 50% of the received results lay within the above limit.

There are several possible reasons for the spread of results.

First, the accuracy of the calibration factors being used may be in error. Unfortunately, with the exception of the NPL calibrator, the ISOCAL IV, the accuracy and traceability of the ^{123}I calibration factors recommended by the manufacturers for most of the commercially available calibrators is not known. Also, these settings may only be valid for a particular container format and which may not be that used in practice. To avoid this, the UK protocol [1] for maintaining the quality of radionuclide calibrator performance recommends that calibration figures should be checked at installation, for the preferred container format, and then rechecked on a regular basis.

Second, as already emphasised in this report earlier (section 5 and 6), any variations in the wall thickness of the solution container can produce large variations in response for ^{123}I and this may be a source of error.

Third, the tolerances for the dimensions and the gas filling of radionuclide calibrators made by the same manufacturer (with the exception of the NPL calibrator) may not be sufficiently tightly controlled or specified. Small variations in the thickness of the inner wall of calibrators of the same type would generate considerable differences in response for low energy gamma emitters, as in the case of ^{123}I. This is exemplified by the results from participant number 18, in Figure 10. The majority of these results (namely from 18[b] to 18[k]) are from measurements made with different Capintec type systems. Results number 18[j] should be excluded from this discussion, as this particular chamber is fitted with an inner PVC liner and a PVC dipper (which generates further attenuation, hence the measurements from this system are about 50 % low), for reasons that have not been specified by the participant. The spread of these Capintec results is up to 33 % lower than the true value, for P6 vial data, and up to 38 % higher than the true value, for syringe data. The differences between the two formats vary between 25 % and 30 %, but it should be noted that the correction factor recommended by Capintec for syringe measurements is only 15 %.

The effect of these possible sources of error on the accuracy of ^{123}I activity measurements is better revealed in the analysis of the data summarised by container type and calibrator type.

The overall data indicated that, for the majority of calibrators, there are no significant differences in response between the “dial” and the “preset” settings for ^{123}I, for either P6 vial or syringe results.

10.3. P6 VIAL RESULTS

The spread of results from measurements made in the P6 vials received are displayed in Figure 5, which shows that less than 2 in every 3 are within ± 10 % of the NPL

value. It also reveals a noticeable tendency to underestimate the activity, as about 70% of the P6 vial results are lower than the NPL value, and most frequently between 5 to 10 % low.

Most worrying are the number of outliers: 12 results are more than 30 % different from the NPL value and almost 1 in 3 of the results are outside the ± 10 % limit.

Some participants have also reported results to which they applied self-determined correction factors, although the method and traceability of their recalibrations was not specified. These particular results are highlighted in Figure 5 and although few are close to the true value, there is now an evident tendency to overestimate the activity. This may be due, in part, to the fact that the initial recalibration was performed with standard P6 vials for which NPL measurements suggest a correction factor of about +10 % for a particular Capintec system (see Figure 3), while the correction factor for the P6 vial type received for this exercise is only + 5 %.

10.3.1. CAPINTEC SYSTEMS

The majority of results from Capintec systems, as displayed in Figure 7, show a similar low bias to the overall P6 vial data, with a spread of up to 15 % lower than the NPL value. This is expected, as about 75% of the P6 vial reported results are from measurements made on Capintec systems.

Measurements made at NPL for this exercise already indicated that the response of a particular Capintec 120 system is about 5 % lower for measurements in the P6 vial type provided for this exercise and using the manufacturer's ^{123}I Calibration factor. This may be partly the reason for the low bias observed, although the large spread of results suggests that this effect is not constant for individual Capintec calibrators, possibly due to variations in the thickness of the inner wall of the chambers, as discussed in section 10.2. It is therefore recommended that these systems should be calibrated individually, in particular for ^{123}I, because of the added errors associated with the low energy emissions.

The results from Capintec 15 calibrators show a wider spread than that of other Capintec systems. Since there are significantly more Capintec 15 systems reporting here than other Capintec systems, it is not clear whether this larger spread is an inherent factor of the Capintec 15 or arises from the larger number of systems included in this comparison. The two extreme results, positioned 50 % lower, are the already identified No 18[j].

10.3.2. ISOCAL IV SYSTEMS

This is the NPL secondary standard radionuclide calibrator. Its design tolerances are sufficiently strict to ensure that the variation in response between chambers at 27 keV emissions is less than 6 %. Each system is calibrated by NPL for the P6 vial measurement format, over a wide range of energy. These calibration measurements have shown that the NPL chambers are, invariably, within 3 % of the published response factor for ^{125}I. The reported results reflect the accuracy of these calibrators

as they all are within 4 % of the NPL value, with the exception of one outlier, as presented in Figure 6.

10.3.3. ISOCAL III SYSTEMS

Only seven results have been reported for these calibrators and, as Figure 6 shows, they centre within 10 % of the true value.

10.3.4. ISOCAL II/PITMAN 238 SYSTEMS

These results have a wider spread of around ± 15 %, biased slightly high. The performance of these systems has consistently been poor over the past intercomparison exercises, for various radionuclides. This is mainly because these chambers are unsealed and therefore subject to pressure and temperature variations and possibly because of suspected errors in the initial calibration.

10.3.5. OTHER SYSTEMS

As only a few results with other calibrators were reported, it is difficult to assess the general performance of these calibrators. However some of the outliers deserve attention. First, one of the results from Veenstra (No 15[g]) is 50 % low, suggesting that either the ^{123}I calibration factor for this system is inaccurate or that there are some potentially serious problems with the performance of this particular system. In the light of the possible errors associated with this chamber, the participant has applied a self-derived correction factor to this result – this time the activity was 17 % higher than the true value. Again, this may be due to the fact that the initial recalibration was done with a standard P6 vial, while the solution sample was measured in a variant P6 vial. With no knowledge of the degree of deviation in response with variation in the wall thickness of the sample container, it is hard to draw any conclusions. The recommendation must be that recalibrations should be done using a traceable solution, for the preferred container.

The two P6 vial results from PITMAN 270 (No 12[c] and No 5[c]) are indeed worrying. Both of them are about 64 % higher than the NPL activity, although the measurements were made on two different calibrators from different hospitals. This suggests that although the response of these chambers may be constant, the manufacturer's calibration factor for ^{123}I is greatly overestimating the activity and it should be revised.

10.4. SYRINGE DATA

The response of radionuclide calibrators is clearly higher for measurements made with solution in plastic containers such as syringes than for those made with glass vials. The container effect is clearly larger for ^{123}I, which emits low energy photons, and this is confirmed by the reported syringe results presented in Figure 8. Approximately 75 % of these values are 15 % to 40 % higher than the NPL activity, with a mean value of 1.21. This high bias suggests that, for the majority of calibrators, the existing ^{123}I calibration factors for syringes overestimate the activity. The implications are considerable as the final activity assays of radioactive solutions, prior to administration to patients, are often made in syringes. The wide spread of results

suggests that the performance of different calibrator types is not similar and recalibrations should be performed individually.

To improve the accuracy of their measurements, some of the participants have applied self-determined correction factors or in-house derived calibration factors. These corrected syringe results are highlighted in Figure 8 and an improvement is noticeable, as they lay within ± 10 % of the true value. Again, it was not specified whether the recalibration was done directly with a standardised solution or if it was derived using a solution measured in-house and, with only eight corrected results, it is difficult to draw any general conclusions.

There are two outliers biased 30 % low: No 18[j] is again from a measurement made on the Capintec system fitted with a PVC liner, which explains the underestimation.
No 23[e] is a SIEL calibrator result, from a measurement made on the recommended 277 dial factor. Interestingly, although no significant variations between the two ^{123}I settings have been noticed for the majority of calibrators, for this particular system, the preset result was 35% higher than the NPL value, while the dial result was 30% low.

The performance of individual systems is revealed in the breakdown of syringe results by calibrator type and presented in Table 3 and Figure 10.

10.4.1. CAPINTEC SYSTEMS

A significant high bias for Capintec syringe results is revealed in the Figure 9, with 80 % of these being between 20 % to 45 % higher than the NPL value. It is therefore evident that the 15 % syringe correction recommended in the Capintec user manual produces erroneous results and that it is not valid for all the syringe types in use. The relatively wide spread of results can be attributed to the already identified variations in the wall thickness of these calibrators. Because there are many types of plastic syringes used in practice, it is best to calibrate individual systems for the preferred syringe format.

10.4.2. ISOCAL SYSTEMS

The ISOCAL results (from all calibrator types), displayed in Figure 9, show the expected high bias for solution measurements in syringes, as they centre about 20 % higher than the NPL result, with a slightly narrower spread than the Capintec data.

For the ISOCAL IV systems, syringe factors have not been published as yet. NPL is in the process of determining calibration factors for the most commonly used syringe types, for a wide range of radionuclides routinely used in medicine. These will then be made available to the user community.

10.5. COPPER INSERTS

As about 50 % of the photons emitted from ^{123}I are in the region of 27 – 31 keV, slight variations in the measurement format produce considerable variations in the response of individual calibrators. By placing a copper insert between the chamber

and the source, the low energy photons can be significantly attenuated and the variations they induce on the overall response of the ionisation chamber minimised. This method is valid if the systems are recalibrated with the copper insert in place.

Some of the participants had reported such results for this exercise. Four of the results (No 8[a]) from Hospital No 8 are from measurements made on a Capintec system with copper insert and they all agree within 0.1 % with the NPL value. As the rest of the non-insert Capintec results (No 8[b]) from this hospital are on average 15 % lower, it is clear that the ^{123}I calibration factor for the calibrator fitted with copper insert was correctly derived.

Surprisingly, for results No 15[d], the non-insert value agrees with the NPL result, while the insert value is 10 % higher, using the same setting (although it was not specified what correction was applied to the insert result).

10.6. LEAD SHIELDING

When calibrators are fitted with lead shielding, a slight increase in their response is expected due to backscattering and appropriate corrections should be applied to account for this effect. Recent measurements performed at NPL show that the response of the NPL radionuclide calibrator, with its designated shield in place (consisting of 2 mm of steel support, 4 mm of lead and 2 mm of aluminium outer cover), is about 3 % higher for standard P6 vials.

However, the results No 21[a] indicate that the response of this ISOCAL IV system fitted with shielding is only 1.6 % higher, possibly the result of a non-standard type of shielding being used (not specified) and because the solution was measured in a variant P6 vial. This suggests that the systems fitted with shielding should be recalibrated for ^{123}I in particular, for the preferred container type.

Result No 13[a] from an Isocal II calibrator cannot be discussed as only the measurement with the shield in place was reported.

11. UNCERTAINTIES

The response to the request for estimates of uncertainty produced more contributions than the previous exercise [5] but the same comments apply as before: the methods of estimation and combination of individual contributions show no consistency. The reported uncertainties, listed in Table 4, are generally too small to account for the spread of results.

12. COMPARISON WITH THE PREVIOUS ^{123}I EXERCISE

The results from the previous and present ^{123}I intercomparisons are presented (as percentages) in Table 5. The overall distribution of P6 vial and syringe results from both exercises is surprisingly similar and the earlier discussions have highlighted why

so many erroneous results could have occurred. However, it was hoped that the recommendations on how to improve the accuracy of the ^{123}I activity measurements that were made in the 1996 Intercomparison report [5] would have resulted in better results. That this has not happened may be influenced by the fact that only two of the participants from the first intercomparison submitted results for the second one. All the other participants were effectively participants for the first time. This already highlights a problem in disseminating intercomparison results, and particularly recommendations, in such a way that they are received and acted upon. This process of knowledge transfer needs to be reviewed.

In addition, it does appear that the manufacturers have not been active either in improving the quality of their calibration figures or advice and this is a matter which needs further consideration.

13. CONCLUSIONS

This exercise has revealed that the accuracy of ^{123}I measurements in the UK hospitals has not improved significantly since the last intercomparison. It identified possible sources of error that explain the inaccuracy of the reported results. The authors propose the following conclusions:

(a) The spreads of P6 vial and syringe results are unacceptably large, with similar distributions to those in the previous intercomparison exercise.

(b) Large variations in response for low energy emitters such as ^{123}I can be produced by small variations in the wall thickness of both the solution container and the inner wall of the calibrator

(c) The recommended calibration factors for most calibrators, with the exception of NPL radionuclide calibrator, produce results that generally underestimate the activity for the P6 vial format.

(d) Recommended syringe factors predominantly overestimate the activity.

(e) Radionuclide calibrators should be recalibrated individually using traceable standards, in the preferred formats, such as P6 vials and syringes

(f) Users of Veenstra, Pitman 270 and Isocal II systems should be particularly concerned about the quality of their supplied calibration factors for ^{123}I.

(g) For calibrators with any additional fittings such as copper insert, lead shielding, etc. ^{123}I factors should be individually derived, for specific containers, using traceable standards.

(h) NPL should provide calibration factors for the NPL calibrator, for the most used syringe types.

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

(j) NPL should continue the ongoing programme of intercomparison exercises.

(k) The nuclear medicine community together with NPL should consider how best to achieve improvements in measurement accuracy.

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Table 1

Comparison of primary standards from National Metrology Institutes (NMIs)

Country	NMI Acronym	NMI Value (Bq/mg)	Uncertainty (k=1) (Bq/mg)
Belgium	CBNM	501	2.7
France	LMRI	500.4	1.4
UK	NPL	502.3	1.2

Table 2

^{123}I solution reported results.

Solution Code	Calibrator Manufacturer	Model	Container Type	Settings	Reported Activity (MBq)	Reported/NPL
1[a]	CAPINTEC	CRC-15R	P6 vial	dial 239	38.75	1.042
1[b]	CAPINTEC	CRC-15R	P6 vial	dial 239	37.99	1.022
1[c]	VINTEN	ISOCAL IV	P6 vial	preset	42.81	1.151
1[d]	CAPINTEC	CRC-15R	P6 vial	dial 239	40.11	1.079
1[e]	CAPINTEC	CRC-15R	P6 vial	dial 239	38.09	1.024
1[f]	CAPINTEC	CRC-15R	P6 vial	dial 239	38.81	1.044
1[g]	CAPINTEC	CRC-15R	P6 vial	dial 235	39.86	1.072
1[h]	CAPINTEC	CRC-15R	P6 vial	dial 235	39.64	1.066
2[a]	CAPINTEC	CRC-15R	P6 vial	preset	34.52	0.916
	CAPINTEC	CRC-15R	P6 vial	dial 277	34.52	0.916
2[b]	CAPINTEC	CRC-15R	P6 vial	preset	33.63	0.892
	CAPINTEC	CRC-15R	P6 vial	dial 277	33.66	0.893
2[c]	CAPINTEC	CRC-15R	P6 vial	preset	34.76	0.922
	CAPINTEC	CRC-15R	P6 vial	dial 277	34.76	0.922
3	CAPINTEC	CRC-15R	P6 vial	dial 277	36.16	0.966
4[a]	CAPINTEC	CRC-15R	P6 vial	preset	35.00	0.941
4[b]	NE Technology	ISOCAL II	P6 vial	dial 1300	41.69	1.120
4[c]	NE Technology	ISOCAL III	P6 vial	dial 0506	37.83	1.017
4[d]	NE Technology	ISOCAL III	P6 vial	dial 0506	36.91	0.992
4[e]	NE Technology	ISOCAL III	P6 vial	dial 0506	36.18	0.972
5[a]	CAPINTEC	CRC-15R	P6 vial	preset	32.88	0.885
	CAPINTEC	CRC-15R	P6 vial	dial 277	32.94	0.887
5[b]	CAPINTEC	CRC-120	P6 vial	preset	34.03	0.916
	CAPINTEC	CRC-120	P6 vial	dial 277	34.18	0.920
5[c]	PITMAN	270	P6 vial	dial 10367	60.82	1.637
6	CAPINTEC	CRC-10RB	P6 vial	preset	34.46	0.925
	CAPINTEC	CRC-10RB	P6 vial	dial 277	34.91	0.937
	CAPINTEC	CRC-10RB	5 ml syringe	preset	47.75	1.300
	CAPINTEC	CRC-10RB	5 ml syringe	dial 277	48.35	1.317
	CAPINTEC	CRC-10RB	residue	dial 277	0.50	0.913
7[a]	CAPINTEC	CRC-35R	P6 vial	preset	39.36	1.056
	CAPINTEC	CRC-35R	5 ml syringe	preset	25.98	1.493
	CAPINTEC	CRC-35R	residue	preset	20.47	1.029
7[b]	PITMAN	238	P6 vial	dial 0569	39.85	1.069
	PITMAN	238	5 ml syringe	dial 0569	19.83	1.139
	PITMAN	238	residue	dial 0569	20.84	1.048
7[c]	VINTEN	ISOCAL II	P6 vial	dial 1263	42.59	1.142
	VINTEN	ISOCAL II	5 ml syringe	dial 1263	21.24	1.221
	VINTEN	ISOCAL II	residue	dial 1263	21.56	1.084
8[a]	CAPINTEC (copper insert)	CRC-15R	P6 vial	dial 051 *	37.48	1.005
	CAPINTEC (copper insert)	CRC-15R	P6 vial	dial 051 *	37.55	1.007
	CAPINTEC (copper insert)	CRC-15R	P6 vial	dial 051 *	37.24	0.999
	CAPINTEC	CRC-15R	P6 vial	dial 051 *	37.31	1.000

Solution Code	Calibrator Manufacturer	Model	Container Type	Settings	Reported Activity (MBq)	Reported/NPL
	(copper insert)					
8[b]	CAPINTEC	ARC-120	P6 vial	preset	32.59	0.874
	CAPINTEC	ARC-120	P6 vial	dial 277	32.95	0.883
	CAPINTEC	ARC-120	P6 vial	preset	32.92	0.883
	CAPINTEC	ARC-120	P6 vial	dial 277	33.24	0.891
	CAPINTEC	ARC-120	P6 vial	preset	32.77	0.879
	CAPINTEC	ARC-120	P6 vial	dial 277	33.06	0.887
	CAPINTEC	ARC-120	P6 vial	preset	32.94	0.883
	CAPINTEC	ARC-120	P6 vial	dial 277	33.34	0.894
9[a]	CAPINTEC	CRC-15R	P6 vial	preset	34.57	0.933
9[b]	CAPINTEC	CRC-10	P6 vial	dial 277	34.94	0.943
10[a]	CAPINTEC	ARC-120	P6 vial	preset	34.85	0.935
	CAPINTEC	ARC-120	P6 vial	dial 277	34.77	0.933
	CAPINTEC	ARC-120	5 ml syringe	preset	48.36	1.306
	CAPINTEC	ARC-120	5 ml syringe	dial 277	48.39	1.307
10[b]	CAPINTEC	CRC-15R	P6 vial	preset	35.28	0.946
	CAPINTEC	CRC-15R	5 ml syringe	preset	47.73	1.289
10[c]	CAPINTEC	CRC-15R	P6 vial	preset	32.63	0.875
	CAPINTEC	CRC-15R	5 ml syringe	preset	43.19	1.167
11[a]	CAPINTEC	CRC-15R	P6 vial	preset	34.94	0.944
11[b]	CAPINTEC	CRC-15R	P6 vial	preset	35.24	0.952
11[c]	VINTEN	ISOCAL II	P6 vial	preset	36.00	0.972
11[d]	VINTEN	ISOCAL II	P6 vial	preset	41.32	1.116
11[e]	VINTEN	ISOCAL II	P6 vial	preset	39.54	1.068
11[f]	VINTEN	ISOCAL II	P6 vial	dial 1300	39.29	1.061
11[g]	VINTEN	ISOCAL IV	P6 vial	preset	37.12	1.003
11[h]	CAPINTEC	CRC-15R	P6 vial	preset	34.44	0.930
11[i]	CAPINTEC	CRC-15R	P6 vial	dial 277	32.03	0.865
11[j]	VINTEN	ISOCAL IV	P6 vial	dial 0506	37.47	1.012
11[k]	NE Technology	ISOCAL IV	P6 vial	preset	38.30	1.035
11[l]	VINTEN	ISOCAL II	P6 vial	dial 1300	38.64	1.044
12[a]	CAPINTEC	CRC-15R	P6 vial	dial 277	35.16	0.942
12[b]	CAPINTEC	CRC-15R	P6 vial	dial 277	34.29	0.918
12[c]	PITMAN	270	P6 vial	dial 10367	61.10	1.637
13[a]	CAPINTEC	CRC-15R	P6 vial	dial 227	33.95	0.916
	CAPINTEC	CRC-15R	P6 vial	dial 192 *	44.38	1.198
	CAPINTEC	CRC-15R	3 ml syringe	preset	23.96	1.277
	CAPINTEC	CRC-15R	3 ml syringe	dial 277	23.96	1.277
	CAPINTEC	CRC-15R	residue	dial 277	19.64	1.073
	CAPINTEC	CRC-15R	Mallinkrodt	preset	25.75	0.729
	CAPINTEC	CRC-15R	Mallinkrodt	dial 277	29.86	0.846
13[b]	CAPINTEC	CRC-15R	P6 vial	dial 192 *	43.29	1.168
13[c]	VINTEN (lead shield)	ISOCAL II	P6 vial	dial 1270	40.14	1.083
13[d]	CAPINTEC	CRC-15R	P6 vial	preset	31.20	0.842
	CAPINTEC	CRC-15R	P6 vial	dial 192 *	40.83	1.102
13[e]	CAPINTEC	CRC-15R	P6 vial	preset	36.42	0.983
	CAPINTEC	CRC-15R	P6 vial	dial 192 *	40.98	1.106
13[f]	CAPINTEC	CRC-15RB	P6 vial	dial 227	40.32	1.088
	CAPINTEC	CRC-15RB	P6 vial	dial 192 *	44.54	1.202
	CAPINTEC	CRC-15RB	3 ml syringe	dial 277	24.30	1.295
	CAPINTEC	CRC-15RB	residue	dial 192 *	22.55	1.232

Solution Code	Calibrator Manufacturer	Model	Container Type	Settings	Reported Activity (MBq)	Reported/NPL
	CAPINTEC	CRC-15RB	Mallinkrodt	dial 277	26.20	0.742
	CAPINTEC	CRC-15RB	Mallinkrodt	dial 192 *	34.12	0.967
14[a]	CAPINTEC	CRC-15R	P6 vial	dial 268 *	36.90	0.995
	CAPINTEC	CRC-15R	P6 vial	dial 277	35.91	0.968
	CAPINTEC	CRC-15R	2.5ml syringe	dial 422 *	17.35	0.967
	CAPINTEC	CRC-15R	residue	dial 268 *	18.88	0.987
14[b]	CAPINTEC	CRC-15R	P6 vial	dial 268 *	36.59	0.986
	CAPINTEC	CRC-15R	P6 vial	dial 277	35.56	0.959
	CAPINTEC	CRC-15R	2.5ml syringe	dial 422 *	17.42	0.970
	CAPINTEC	CRC-15R	residue	dial 268 *	18.88	0.987
15[a]	CAPINTEC	CRC-15R	P6 vial	dial 220 *	37.36	1.000
	CAPINTEC	CRC-15R	P6 vial	dial 220 *	36.98	0.989
	CAPINTEC	CRC-15R	2 ml syringe	dial 380	9.09	0.982
	CAPINTEC	CRC-15R	residue	dial 220 *	27.44	0.976
15[b]	VINTEN	ISOCAL II	P6 vial	dial 0506	35.88	0.960
	VINTEN	ISOCAL II	2 ml syringe	dial 0506	10.82	1.169
	VINTEN	ISOCAL II	2 ml syringe	dial 0539	10.15	1.096
	VINTEN	ISOCAL II	residue	dial 0506	27.64	0.983
15[c]	CAPINTEC	CRC-15B	P6 vial	dial 277	31.28	0.837
	CAPINTEC	CRC-15B	P6 vial	dial 220 *	37.19	0.995
15[d]	CAPINTEC	CRC-15R	P6 vial	dial 277	36.83	0.985
	CAPINTEC (with insert)	CRC-15R	P6 vial	dial 277	37.71	1.009
15[e]	CAPINTEC	CRC-15R	P6 vial	dial 277	35.19	0.942
	CAPINTEC	CRC-15R	P6 vial	dial 220 *	41.86	1.120
15[f]	CAPINTEC	CRC-7B	P6 vial	dial 277	34.17	0.914
	CAPINTEC	CRC-7B	P6 vial	dial 220 *	40.54	1.085
15[g]	VEENSTRA	VDC-405	P6 vial	dial 618	19.94	0.534
	VEENSTRA	VDC-406	P6 vial	dial 116 *	45.29	1.212
15[h]	SIEL	BK-1	P6 vial	preset	33.30	0.891
15[i]	ATOMLAB	ATOMLAB 200	P6 vial	dial 12.9	31.59	0.845
16[a]	CAPINTEC	CRC-15R	P6 vial	preset	34.99	0.940
	CAPINTEC	CRC-15R	2.5 ml syringe	preset	23.56	1.326
	CAPINTEC	CRC-15R	residue	preset	18.06	0.929
16[b]	CAPINTEC	ARC-120	P6 vial	preset	35.69	0.959
	CAPINTEC	ARC-120	P6 vial	dial 277	35.50	0.954
	CAPINTEC	ARC-120	2.5 ml syringe	preset	24.51	1.379
	CAPINTEC	ARC-120	2.5 ml syringe	dial 277	24.42	1.374
	CAPINTEC	ARC-120	residue	preset	18.44	0.949
17[a]	AMERSHAM	ARC-120	P6 vial	preset	35.10	0.945
	AMERSHAM	ARC-120	P6 vial	dial 277	35.40	0.953
	AMERSHAM	ARC-120	2 ml syringe	preset	24.63	1.305
	AMERSHAM	ARC-120	2 ml syringe	dial 277	24.74	1.310
	AMERSHAM	ARC-120	residue	preset	18.02	0.987
17[b]	CAPINTEC	CRC-120	P6 vial	preset	34.37	0.925
	CAPINTEC	CRC-120	P6 vial	dial 277	34.63	0.932
17[c]	CAPINTEC	CRC-15R	P6 vial	preset	34.74	0.935
	CAPINTEC	CRC-15R	P6 vial	dial 277	34.73	0.935
17[d]	CAPINTEC	CRC-712M	P6 vial	dial 277	38.48	1.036
17[e]	CAPINTEC	CRC-15R	P6 vial	preset	35.50	0.956
	CAPINTEC	CRC-15R	P6 vial	dial 277	35.56	0.957
17[f]	CAPINTEC	CRC-15R	P6 vial	preset	33.76	0.909

Solution Code	Calibrator Manufacturer	Model	Container Type	Settings	Reported Activity (MBq)	Reported/NPL
	CAPINTEC	CRC-15R	P6 vial	dial 277	33.61	0.905
17[g]	CAPINTEC	CRC-15R	P6 vial	preset	22.99	0.619
	CAPINTEC	CRC-15R	P6 vial	dial 277	23.01	0.619
17[h]	AMERSHAM	ARC-120	P6 vial	preset	34.02	0.916
	AMERSHAM	ARC-120	P6 vial	dial 277	34.02	0.916
17[i]	CAPINTEC	CRC-15R	P6 vial	preset	34.39	0.926
	CAPINTEC	CRC-15R	P6 vial	dial 277	34.46	0.928
17[j]	CAPINTEC	CRC-15R	P6 vial	preset	48.28	1.300
	CAPINTEC	CRC-15R	P6 vial	dial 277	48.23	1.298
17[k]	AMERSHAM	ARC-120	P6 vial	preset	35.09	0.945
	AMERSHAM	ARC-120	P6 vial	dial 277	35.15	0.946
18[a]	NE Technology	ISOCAL IV	P6 vial	dial 506	38.42	1.031
	NE Technology	ISOCAL IV	P6 vial	dial 506	25.30	1.018
	NE Technology	ISOCAL IV	P6 vial	dial 506	25.38	1.021
	NE Technology	ISOCAL IV	residue	dial 506	1.98	1.083
18[b]	CAPINTEC	CRC-12	P6 vial	preset	33.89	0.910
	CAPINTEC	CRC-12	P6 vial	dial 277	33.89	0.910
	CAPINTEC	CRC-12	1 ml syringe	preset	4.90	1.283
	CAPINTEC	CRC-12	1 ml syringe	dial 277	4.88	1.278
		CRC-12	residue	preset	1.77	0.967
18[c]	CAPINTEC	CRC-35R	P6 vial	dial 277	34.00	0.913
	CAPINTEC	CRC-35R	1ml syringe	dial 277	4.85	1.269
	CAPINTEC	CRC-35R	residue	dial 277	1.74	0.947
18[d]	CAPINTEC	CRC-35R	P6 vial	dial 277	32.46	0.871
	CAPINTEC	CRC-35R	1 ml syringe	dial 277	4.72	1.236
	CAPINTEC	CRC-35R	residue	dial 277	1.66	0.908
18[e]	CAPINTEC	CRC-35R	P6 vial	dial 277	33.77	0.906
	CAPINTEC	CRC-35R	P6 vial	preset	33.77	0.906
	CAPINTEC	CRC-35R	1 ml syringe	dial 277	4.89	1.281
	CAPINTEC	CRC-35R	residue	dial 277	1.72	0.937
18[f]	AMERSHAM	ARC-120	P6 vial	preset	36.34	0.975
	AMERSHAM	ARC-120	P6 vial	dial 277	36.56	0.981
	AMERSHAM	ARC-120	1 ml syringe	preset	5.28	1.383
	AMERSHAM	ARC-120	residue	preset	1.80	0.983
18[g]	CAPINTEC	CRC-15	P6 vial	preset	32.57	0.874
	CAPINTEC	CRC-15	P6 vial	dial 277	32.57	0.874
	CAPINTEC	CRC-15	1 ml syringe	dial 277	4.60	1.203
	CAPINTEC	CRC-15	residue	dial 277	1.65	0.899
18[h]	CAPINTEC	CRC-15	P6 vial	preset	32.37	0.869
	CAPINTEC	CRC-15	P6 vial	dial 277	32.37	0.869
	CAPINTEC	CRC-15	1 ml syringe	dial 277	4.67	1.222
	CAPINTEC	CRC-15	residue	dial 277	1.47	0.802
18[i]	CAPINTEC	CRC-15	P6 vial	preset	34.86	0.936
	CAPINTEC	CRC-15	P6 vial	dial 277	34.86	0.936
	CAPINTEC	CRC-15	2 ml syringe	dial 277	8.78	1.333
	CAPINTEC	CRC-15	residue	dial 277	1.78	0.972
18[j]	CAPINTEC (PVC liner)	CRC-15	P6 vial	preset	19.35	0.520
	CAPINTEC (PVC liner)	CRC-15	P6 vial	dial 277	19.35	0.520
	CAPINTEC (PVC liner)	CRC-15	2 ml syringe	dial 277	5.22	0.792

Solution Code	Calibrator Manufacturer	Model	Container Type	Settings	Reported Activity (MBq)	Reported/NPL
18[k]	CAPINTEC	CRC-15	P6 vial	preset	25.39	0.682
	CAPINTEC	CRC-15	P6 vial	dial 277	25.39	0.682
	CAPINTEC	CRC-15	2 ml syringe	dial 277	6.02	0.914
	CAPINTEC	CRC-15	residue	dial 277	1.26	0.690
19[a]	CAPINTEC	CRC-15R	P6 vial	dial 277	37.83	1.016
	CAPINTEC	CRC-15R	P6 vial	dial 277 *	45.59	1.225
	CAPINTEC	CRC-15R	2 ml syringe	dial 277	11.02	1.309
	CAPINTEC	CRC-15R	5 ml syringe	dial 277	22.28	1.262
	CAPINTEC	CRC-15R	2 ml syringe	dial 277 *	7.94	0.942
	CAPINTEC	CRC-15R	5 ml syringe	dial 277 *	16.93	0.959
	CAPINTEC	CRC-15R	residue	dial 277	11.84	1.061
	CAPINTEC	CRC-15R	residue	dial 277 *	15.09	1.352
19[b]	VINTEN	ISOCAL II	P6 vial	dial 1300	43.08	1.157
	VINTEN	ISOCAL II	2 ml syringe	dial 1300	10.78	1.280
	VINTEN	ISOCAL II	5 ml syringe	dial 1300	21.97	1.245
	VINTEN	ISOCAL II	residue	dial 1300	13.29	1.191
20[a]	AMERSHAM	ARC-120	P6 vial	preset	34.45	0.927
20[b]	CAPINTEC	CRC-15R	P6 vial	preset	34.60	0.931
20[c]	VEENSTRA	VDC-404	P6 vial	preset	34.05	0.916
	VEENSTRA	VDC-404	5 ml syringe	preset	25.44	1.180
	VEENSTRA	VDC-404	residue	preset	14.21	0.910
21[a]	NE Technology	ISOCAL IV	P6 vial	preset	38.12	1.025
	NE Technology (lead shield)	ISOCAL IV	P6 vial	preset	38.76	1.042
	NE Technology	ISOCAL IV	P6 vial	dial 0506	38.81	1.044
	NE Technology	ISOCAL IV	2 ml syringe	preset	21.71	1.127
	NE Technology	ISOCAL IV	residue	preset	18.86	1.052
21[b]	VEENSTRA	VDC 304	P6 vial	dial 618 *	34.70	0.933
22[a]	VINTEN	ISOCAL II	P6 vial	dial 1300	40.72	1.094
	VINTEN	ISOCAL II	2 ml syringe	dial 1300	23.16	1.226
	VINTEN	ISOCAL II	residue	dial 1300	20.67	1.127
	VINTEN	ISOCAL II	10R1 vial	dial 1300	21.38	1.160
	VINTEN	ISOCAL II	residue	dial 1300	20.67	1.127
22[b]	VINTEN	ISOCAL IV	P6 vial	dial 0506	38.31	1.029
22[c]	CAPINTEC	CRC-15R	P6 vial	preset	34.22	0.919
22[d]	VINTEN	ISOCAL II	P6 vial	dial 2281	34.45	0.925
22[e]	VINTEN	ISOCAL II	P6 vial	dial 1300	41.48	1.114
22[f]	VINTEN	ISOCAL II	P6 vial	dial 1300	41.76	1.122
22[g]	BIODEX	ATOMLAB 100	P6 vial	preset	30.51	0.820
	BIODEX	ATOMLAB 100	P6 vial	dial 12.9	30.51	0.820
22[h]	VINTEN	ISOCAL III	P6 vial	dial 0506	36.62	0.984
22[i]	VINTEN	ISOCAL III	P6 vial	dial 0506	36.54	0.982
23[a]	CAPINTEC	CRC-10R	P6 vial	preset	34.14	0.920
	CAPINTEC	CRC-10R	P6 vial	dial 277	34.55	0.932
	CAPINTEC	CRC-10R	2 ml syringe	preset	13.37	1.267
	CAPINTEC	CRC-10R	2 ml syringe	dial 277	13.62	1.291
	CAPINTEC	CRC-10R	residue	preset	24.01	0.905
23[b]	CAPINTEC	CRC-10R	P6 vial	preset	31.79	0.857
	CAPINTEC	CRC-10R	P6 vial	dial 277	31.03	0.837
	CAPINTEC	CRC-10R	2 ml syringe	preset	13.29	1.260
	CAPINTEC	CRC-10R	2 ml syringe	dial 277	12.95	1.228
	CAPINTEC	CRC-10R	residue	preset	22.14	0.834

Solution Code	Calibrator Manufacturer	Model	Container Type	Settings	Reported Activity (MBq)	Reported/NPL
23[c]	CAPINTEC	CRC-120R	P6 vial	preset	32.95	0.888
	CAPINTEC	CRC-120R	P6 vial	dial 277	32.98	0.889
	CAPINTEC	CRC-120R	2 ml syringe	preset	13.16	1.247
	CAPINTEC	CRC-120R	2 ml syringe	dial 277	13.18	1.249
	CAPINTEC	CRC-120R	residue	preset	23.34	0.880
23[d]	CAPINTEC	CRC-15R	P6 vial	preset	31.87	0.859
	CAPINTEC	CRC-15R	P6 vial	dial 277	31.90	0.860
	CAPINTEC	CRC-15R	2 ml syringe	preset	12.61	1.195
	CAPINTEC	CRC-15R	2 ml syringe	dial 277	12.62	1.196
	CAPINTEC	CRC-15R	residue	preset	22.27	0.839
23[e]	SIEL	BIC-1	P6 vial	preset	23.46	0.632
	SIEL	BIC-1	2 ml syringe	preset	14.27	1.353
	SIEL	BIC-1	2 ml syringe	dial 277	7.55	0.715
	SIEL	BIC-1	residue	dial 277	22.99	0.866
24[a]	VINTEN	ISOCAL II	P6 vial	dial 1300	40.34	1.088
24[b]	VINTEN	ISOCAL II	P6 vial	dial 1300	40.18	1.084
24[c]	VINTEN	ISOCAL II	P6 vial	dial 1300	40.99	1.105
24[d]	CAPINTEC	CRC-15R	P6 vial	preset	35.05	0.945
24[e]	CAPINTEC	CRC-15R	P6 vial	preset	35.45	0.956
	CAPINTEC	CRC-15R	P6 vial	dial 277	35.60	0.960
24[f]	ATOMLAB	ATOMLAB 200	P6 vial	preset	33.61	0.906
25[a]	CAPINTEC	CRC-120	P6 vial	dial 180 *	50.28	1.357
	CAPINTEC	CRC-120	P6 vial	dial 277	37.02	0.999
	CAPINTEC	CRC-120	5 ml syringe	dial 370 *	39.92	1.078
	CAPINTEC	CRC-120	5 ml syringe	dial 277	50.07	1.353
25[b]	CAPINTEC	CRC-15R	P6 vial	dial 180 *	46.44	1.254
	CAPINTEC	CRC-15R	P6 vial	dial 277	33.94	0.916
	CAPINTEC	CRC-15R	5 ml syringe	dial 370 *	36.08	0.975
	CAPINTEC	CRC-15R	5 ml syringe	dial 277	45.48	1.229
25[c]	CAPINTEC	CRC-15R	P6 vial	dial 180 *	46.32	1.250
	CAPINTEC	CRC-15R	P6 vial	dial 277	33.90	0.915
	CAPINTEC	CRC-15R	5 ml syringe	dial 370 *	36.09	0.975
	CAPINTEC	CRC-15R	5 ml syringe	dial 277	45.40	1.226
25[d]	CAPINTEC	CRC-120	P6 vial	dial 180 *	49.09	1.325
	CAPINTEC	CRC-120	P6 vial	dial 277	35.97	0.971
	CAPINTEC	CRC-120	5 ml syringe	dial 370 *	39.62	1.070
	CAPINTEC	CRC-120	5 ml syringe	dial 277	48.93	1.322
26[a]	CAPINTEC	CRC-120R	P6 vial	preset	36.08	0.967
	CAPINTEC	CRC-120R	P6 vial	dial 277	35.90	0.962
	CAPINTEC	CRC-120R	5 ml syringe	preset	48.62	1.348
	CAPINTEC	CRC-120R	5 ml syringe	dial 277	48.35	1.310
26[b]	CAPINTEC	CRC-15R	P6 vial	preset	35.38	0.948
	CAPINTEC	CRC-15R	P6 vial	dial 277	35.41	0.949
	CAPINTEC	CRC-15R	5 ml syringe	preset	47.13	1.307
26[c]	CAPINTEC	CRC-120R	P6 vial	preset	35.78	0.959
	CAPINTEC	CRC-120R	P6 vial	dial 277	35.81	0.960
	CAPINTEC	CRC-120R	5 ml syringe	preset	48.02	1.332
	CAPINTEC	CRC-120R	5 ml syringe	dial 277	47.98	1.331
	CAPINTEC	CRC-120R	residue	dial 277	1.20	0.960
27[a]	CAPINTEC	CRC-15R	P6 vial	preset	31.65	0.853
	CAPINTEC	CRC-15R	P6 vial	dial 277	31.68	0.854
	CAPINTEC	CRC-15R	syringe	preset	16.65	1.232

Solution Code	Calibrator Manufacturer	Model	Container Type	Settings	Reported Activity (MBq)	Reported/NPL
	CAPINTEC	CRC-15R	syringe	dial 277	16.61	1.229
	CAPINTEC	CRC-15R	residue	preset	19.80	0.840
27[b]	CAPINTEC	CRC-12	P6 vial	preset	35.19	0.949
	CAPINTEC	CRC-12	P6 vial	dial 277	35.16	0.948
	CAPINTEC	CRC-12	syringe	preset	18.33	1.356
	CAPINTEC	CRC-12	syringe	dial 277	18.38	1.361
	CAPINTEC	CRC-12	residue	preset	22.39	0.949
27[c]	CAPINTEC	CRC-10	P6 vial	preset	34.90	0.941
	CAPINTEC	CRC-10	P6 vial	dial 277	35.08	0.946
	CAPINTEC	CRC-10	syringe	preset	15.97	1.182
	CAPINTEC	CRC-10	syringe	dial 277	16.01	1.185
	CAPINTEC	CRC-10	residue	preset	22.16	0.940
27[d]	CAPINTEC	CRC-15R	P6 vial	preset	32.01	0.863
	CAPINTEC	CRC-15R	P6 vial	dial 277	31.98	0.862
	CAPINTEC	CRC-15R	syringe	preset	16.63	1.231
	CAPINTEC	CRC-15R	syringe	dial 277	16.65	1.232
	CAPINTEC	CRC-15R	residue	preset	20.04	0.850
27[e]	VINTEN	ISOCAL III	P6 vial	preset	38.25	1.031
	VINTEN	ISOCAL III	P6 vial	dial 277	38.31	1.033
	VINTEN	ISOCAL III	syringe	preset	14.76	1.092
	VINTEN	ISOCAL III	syringe	dial 277	14.80	1.095
	VINTEN	ISOCAL III	residue	preset	23.80	1.009

Table 3

Results summarised by calibrator and container (ratios of reported results / NPL value)

^{123}I DATA GROUPS	0.50 to 0.55	0.55 to 0.60	0.60 to 0.65	0.65 to 0.70	0.70 to 0.75	0.75 to 0.80	0.80 to 0.85	0.85 to 0.90	0.90 to 0.95	0.95 to 1.00	1.00 to 1.05	1.05 to 1.10	1.10 to 1.15	1.15 to 1.20	1.20 to 1.25	1.25 to 1.30	1.30 to 1.35	1.35 to 1.40	1.40 to 1.60	1.60 to 1.65
ALL DATA (318)	3	0	3	3	3	1	11	33	72	49	27	23	13	13	19	17	16	9	1	2
Container data:																				
P6 VIAL	3	0	3	2	0	0	6	29	60	33	24	13	9	4	3	4	1	1	0	2
RESIDUE DATA	0	0	0	1	0	0	4	4	10	9	3	5	2	1	1	0	0	1	0	0
SYRINGE DATA	0	0	0	0	1	1	0	0	2	6	0	5	2	7	15	13	15	7	1	0
OTHER CONTAINERS	0	0	0	0	2	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0
Chamber data (P6 vial):																				
ISOCAL II/PITMAN238	0	0	0	0	0	0	0	0	1	2	1	7	6	1	0	0	0	0	0	0
ISOCAL III	0	0	0	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	0	0
ISOCAL IV	0	0	0	0	0	0	0	0	0	0	10	0	0	1	0	0	0	0	0	0
CAPINTEC 120	0	0	0	0	0	0	0	10	12	11	0	0	0	0	0	0	1	1	0	0
CAPINTEC 35	0	0	0	0	0	0	0	1	3	0	0	1	0	0	0	0	0	0	0	0
CAPINTEC 15	2	0	2	2	0	0	2	16	29	16	9	4	3	2	2	4	0	0	0	0
CAPINTEC 12	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
CAPINTEC 10	0	0	0	0	0	0	1	1	7	0	0	0	0	0	0	0	0	0	0	0
CAPINTEC 7	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
CAPINTEC 712	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
VEENSTRA	1	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0
SIEL	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
ATOMLAB	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0
PITMAN 270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Chamber data (syringe):																				
CAPINTEC	0	0	0	0	0	1	0	0	2	6	0	2	0	5	12	12	15	6	1	0
ISOCAL	0	0	0	0	0	0	0	0	0	0	0	3	1	1	3	1	0	0	0	0
OTHER SYSTEMS	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0

Table 4

Reported uncertainties

Participant	Type A uncertainty (random)	Type B uncertainty (non-random)	Overall uncertainty
2[a]	1%	3.4%	3.6%
2[b]	1%	3.4%	3.6%
2[c]	1%	3.4%	3.6%
3	0.17%	0.14%	0.31%
5[a]	0.8%	4.5%	4.5%
5[b]	0.4%	5%	5%
5[c]	0.7%	5.5%	5.5%
10[a]	0.25%		
	0.67%		
10[b]	0.22%		
10[c]	0.35%		
11[a]	0.3%	1.7%	2%
11[b]	0.3%	1.7%	2%
11[c]	0.3%	1.7%	2%
11[d]	0.3%	1.7%	2%
11[e]	0.3%	1.7%	2%
11[f]	0.5%		
11[g]	1.1%		
11[h]	0.2%		
11[i	0.1%		
11[j]	0.5%		
11[k]	0.5%		
11[l]	0.4%		
12[a]	negligible	1.36%	1.36%
12[b]	negligible	1.36%	1.36%
12[c]	negligible	3%	3%
13[b]	6.22%		
13[c]	6.03%		
15[a]			3%
15[b]	0.1%	2.5%	2.5%
16[a]	0.14%		
16[b]	0.5%		
18[a]	0.5%	1%	1%
18[b]	1%	12%	
18[c]	1%		
18[d]	1%		
18[e]	1%		
18[f]	1%		
18[g]	1%		
18[h]	1%		

Participant	Type A uncertainty (random)	Type B uncertainty (non-random)	Overall uncertainty
18[i	1%	16%	
18[j]	1%		
19[a]	3%	2%	3.5%
19[b]	4%	3%	5%
21[a]	2%		2%
21[b]	2-3%		3-4%
24[a]	0.1%	5.3%	5.3%
24[b]	0.1%	5.3%	5.3%
24[c]	0.1%	5.3%	5.3%
24[d]	0.07%	3.4%	3.4%
24[e]			5%
24[f]	1.5%		5%
26[a]	0.08%		1.9%
26[b]	0.11%		1.9%
26[c]	0.10%		1.9%

Table 5

Distribution of results from previous and present ^{123}I intercomparisons
(expressed as percentage of results within given range of NPL value)

		RANGE			
YEAR	**DATA GROUP**	0.95 - 1.05	0.90 - 1.10	0.60 - 1.00	1.00 - 1.40
1996	P6 vial Data	28%	62%	72%	27%
	Syringe Data	5%	18%	8%	87%
2000	P6 vial Data	29%	66%	68%	30%
	Syringe Data	8%	17%	13%	85%

Figure 1

Comparison of primary standards from National Metrology Institutes (NMIs)

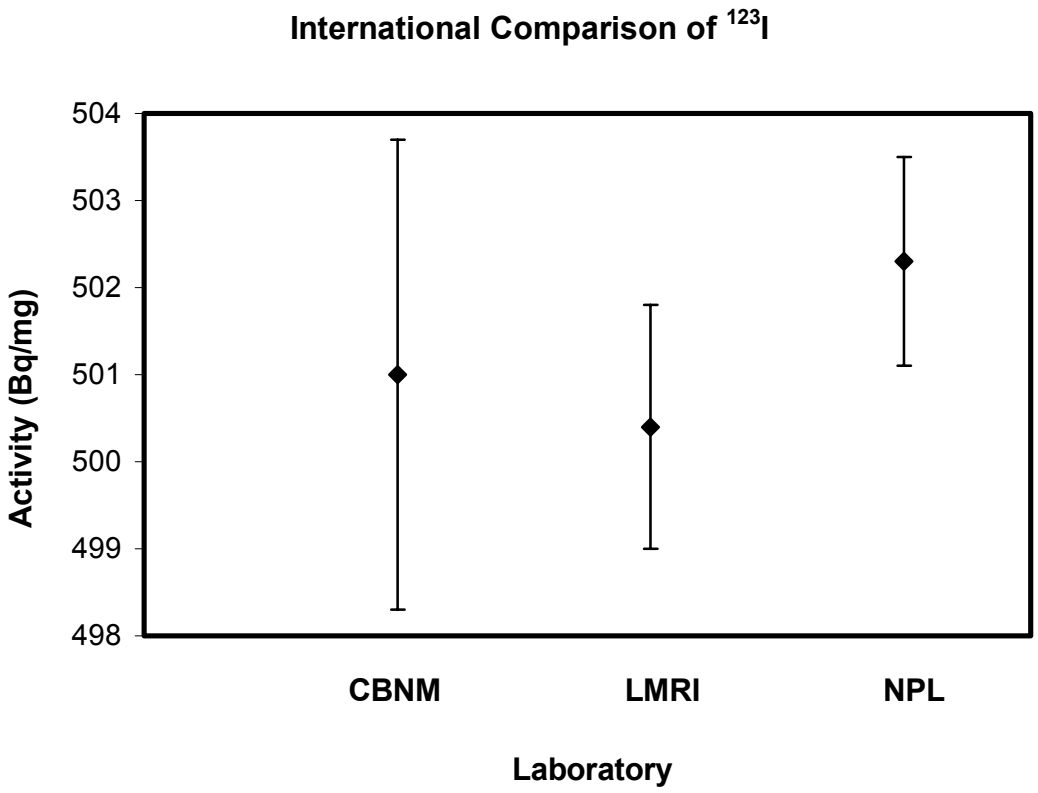


Figure 2 Variation in response with P6 vial type for ISOCAL IV (NPL secondary standard calibrator)

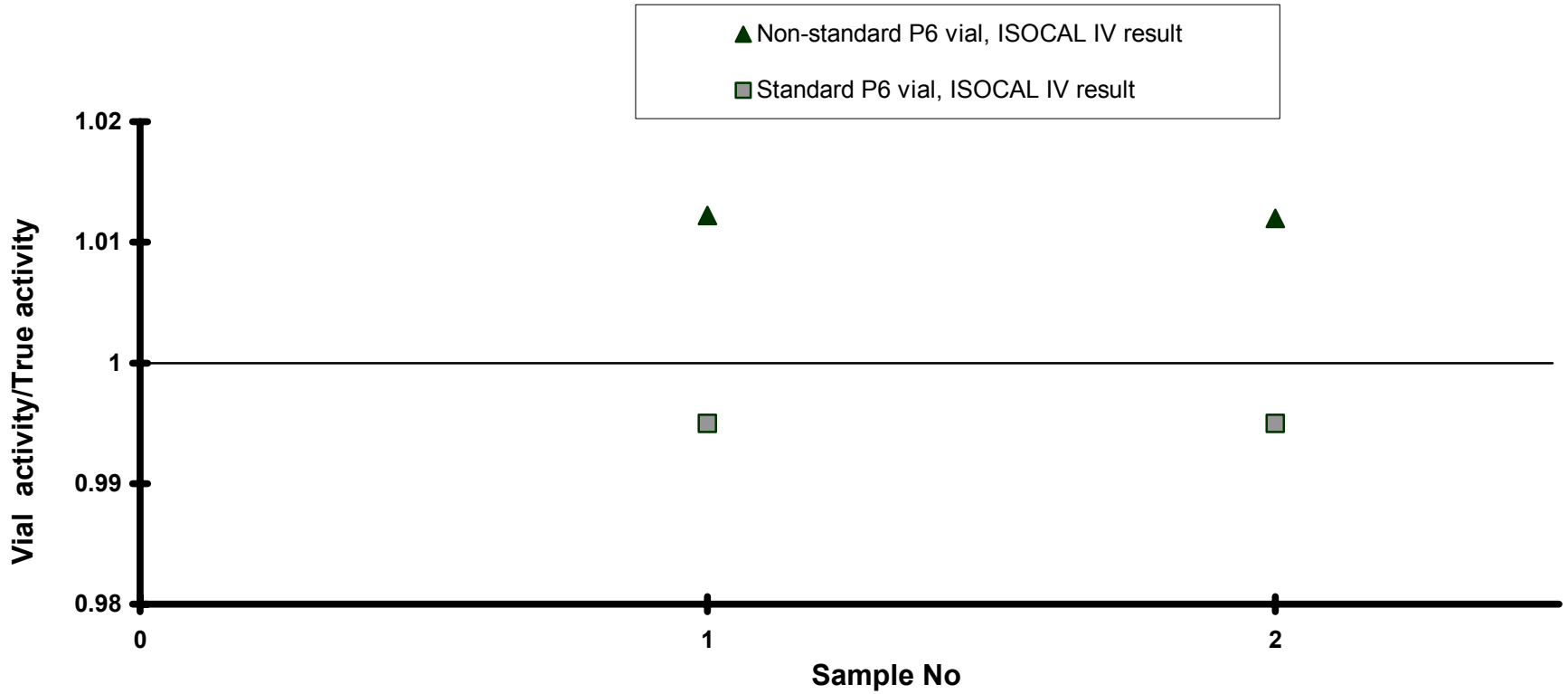


Figure 3 Variation in response with P6 vial type for CAPINTEC ARC 120

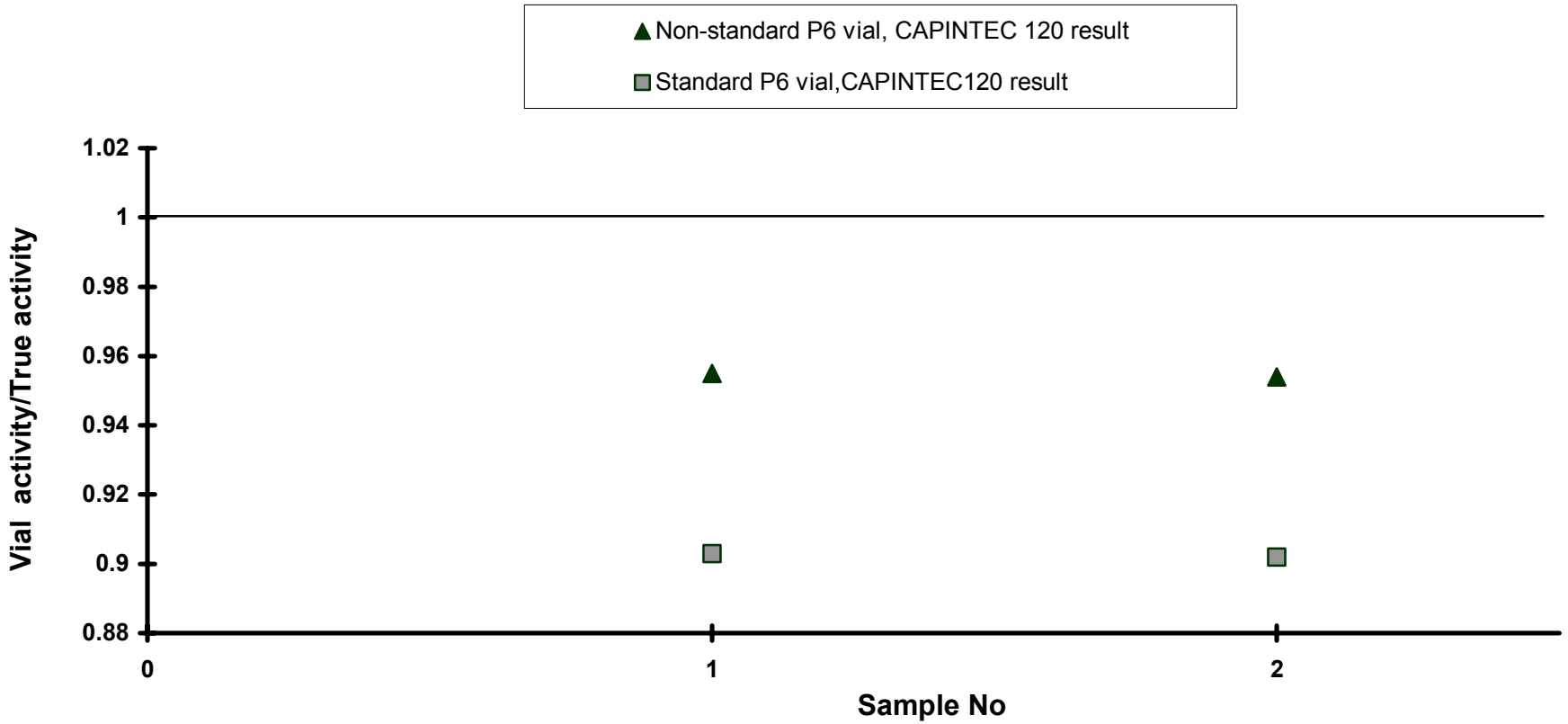


Figure 4 Distribution of results – all systems, all containers

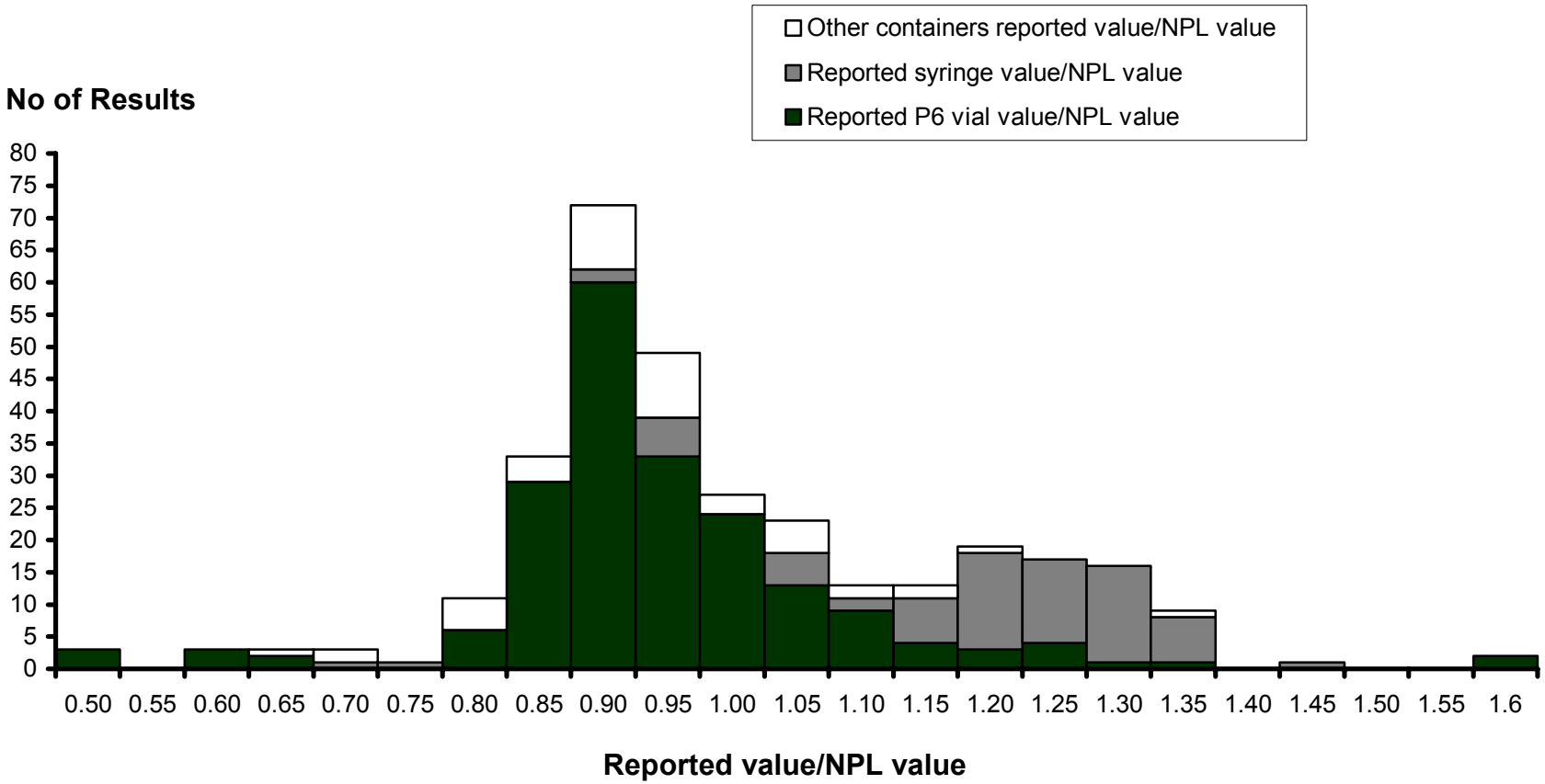


Figure 5 Distribution of P6 vial results – all systems

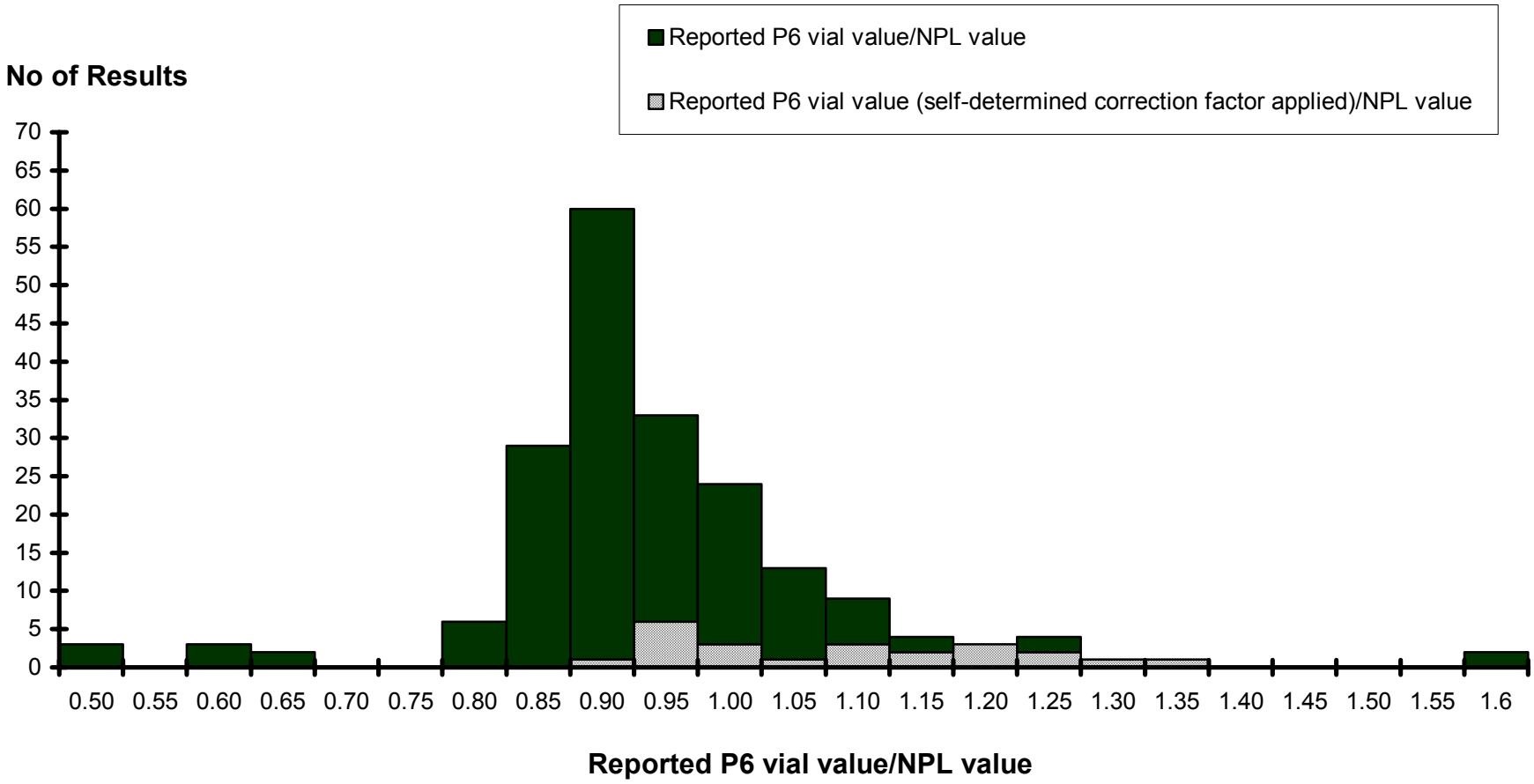


Figure 6 Distribution of P6 vial results – ISOCAL systems

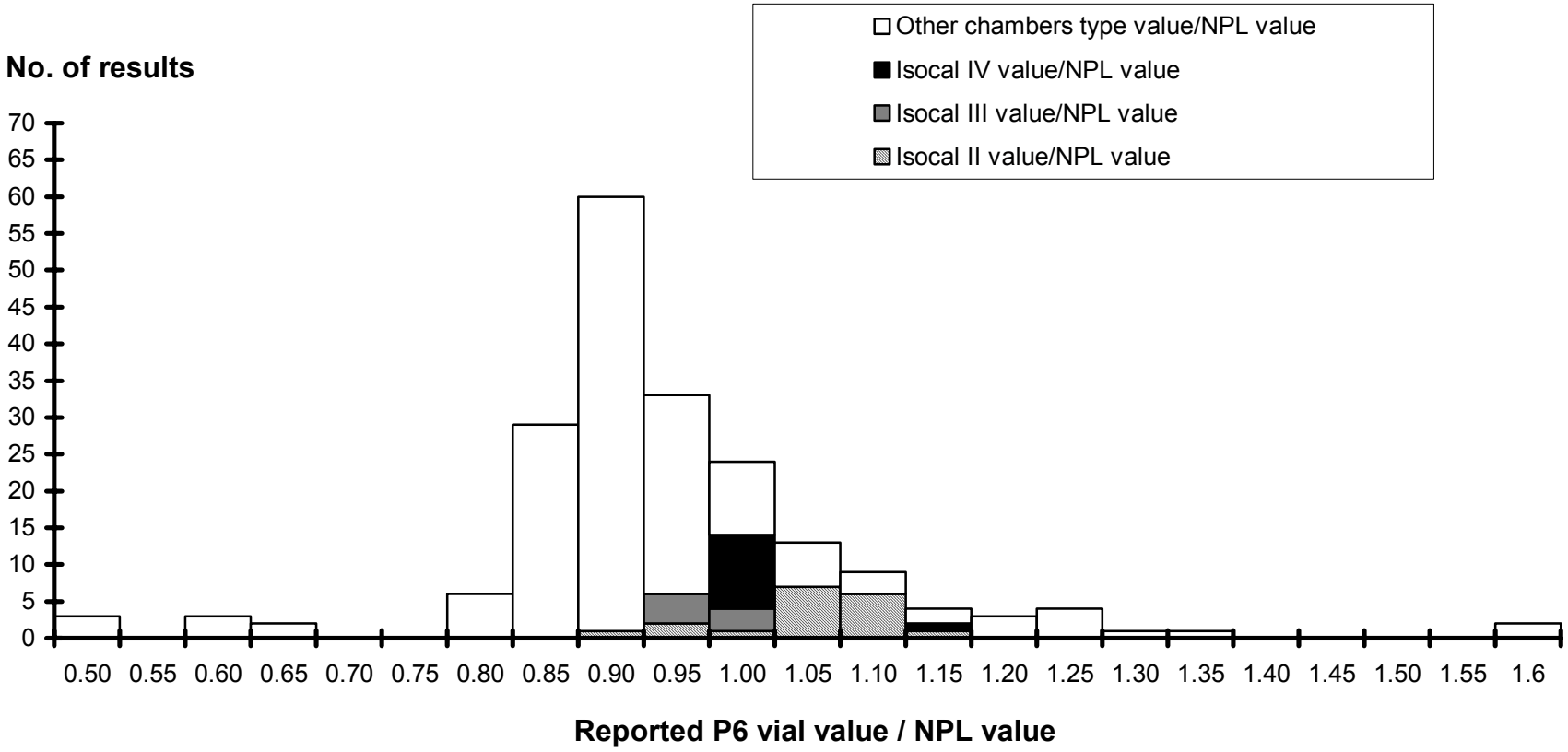


Figure 7 Distribution of P6 vial results – CAPINTEC systems

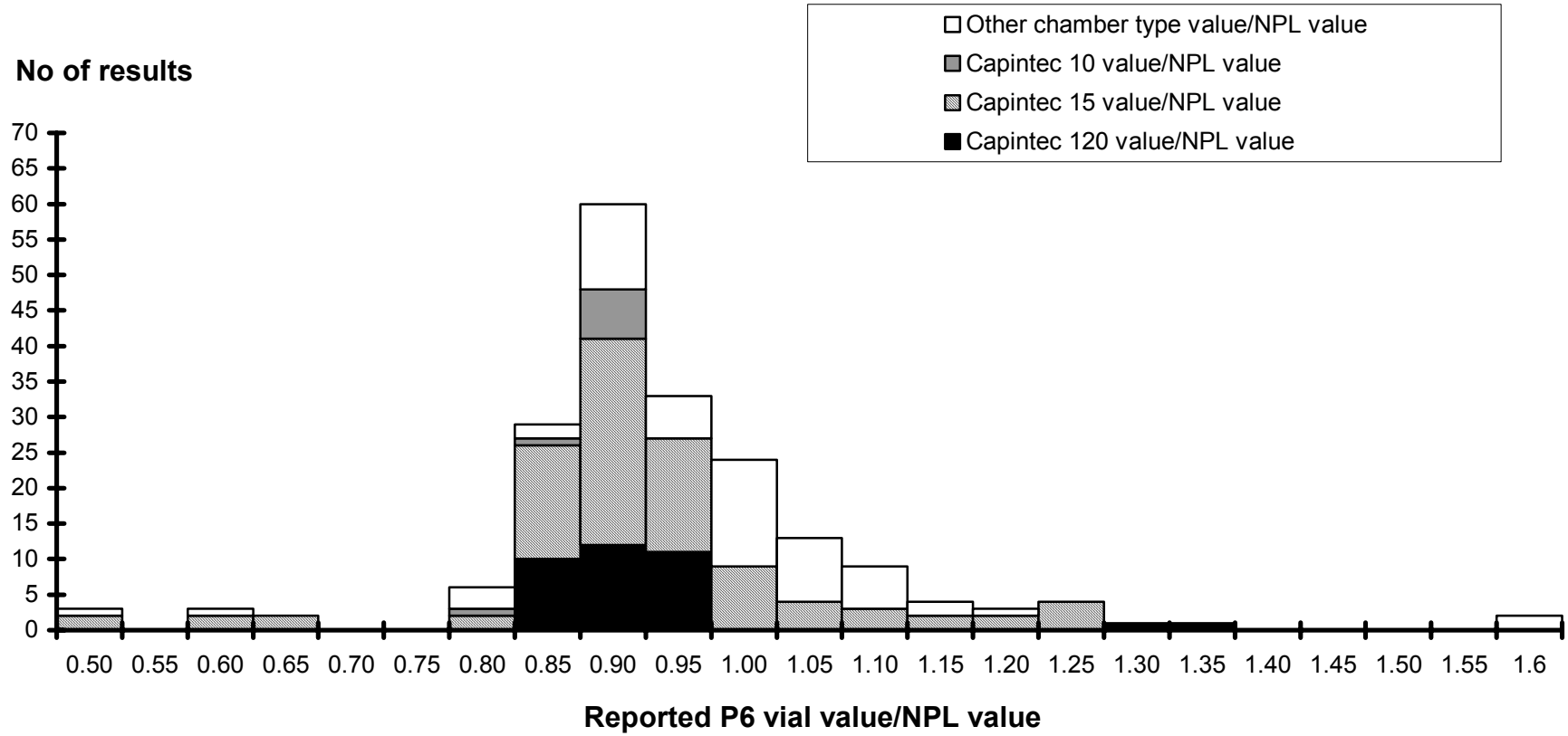


Figure 8 Distribution of syringe results – all systems

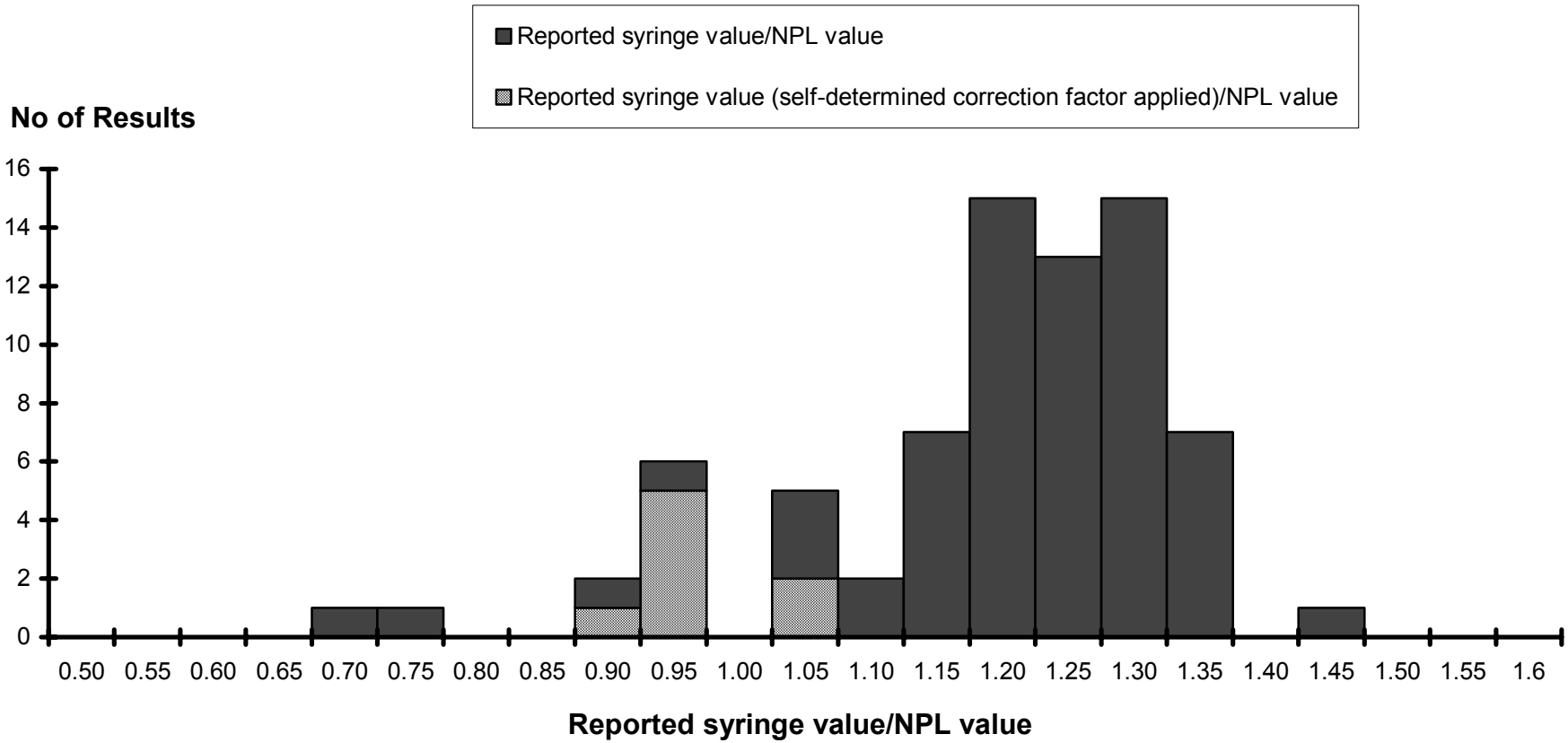


Figure 9 Distribution of syringe results – ISOCAL and CAPINTEC systems

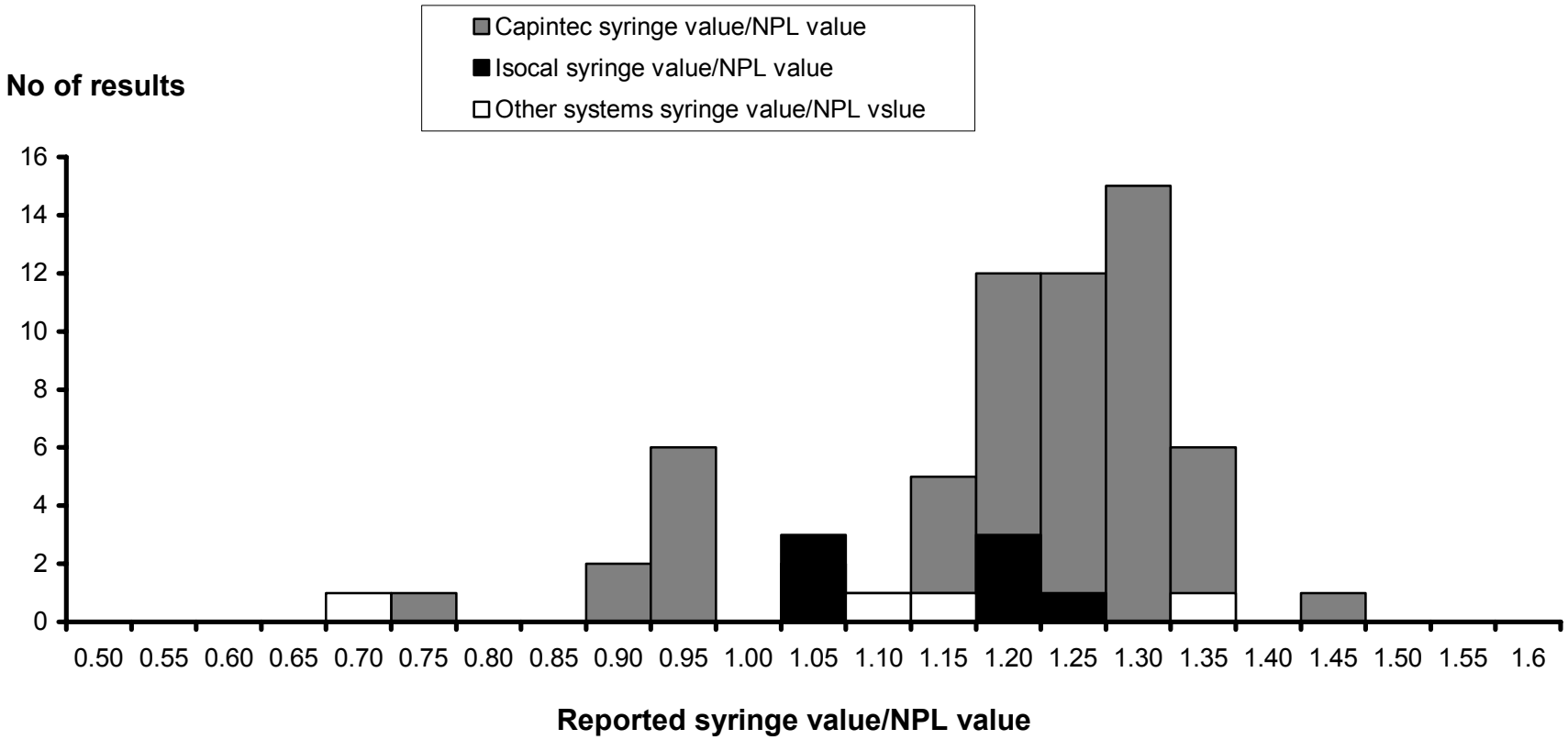
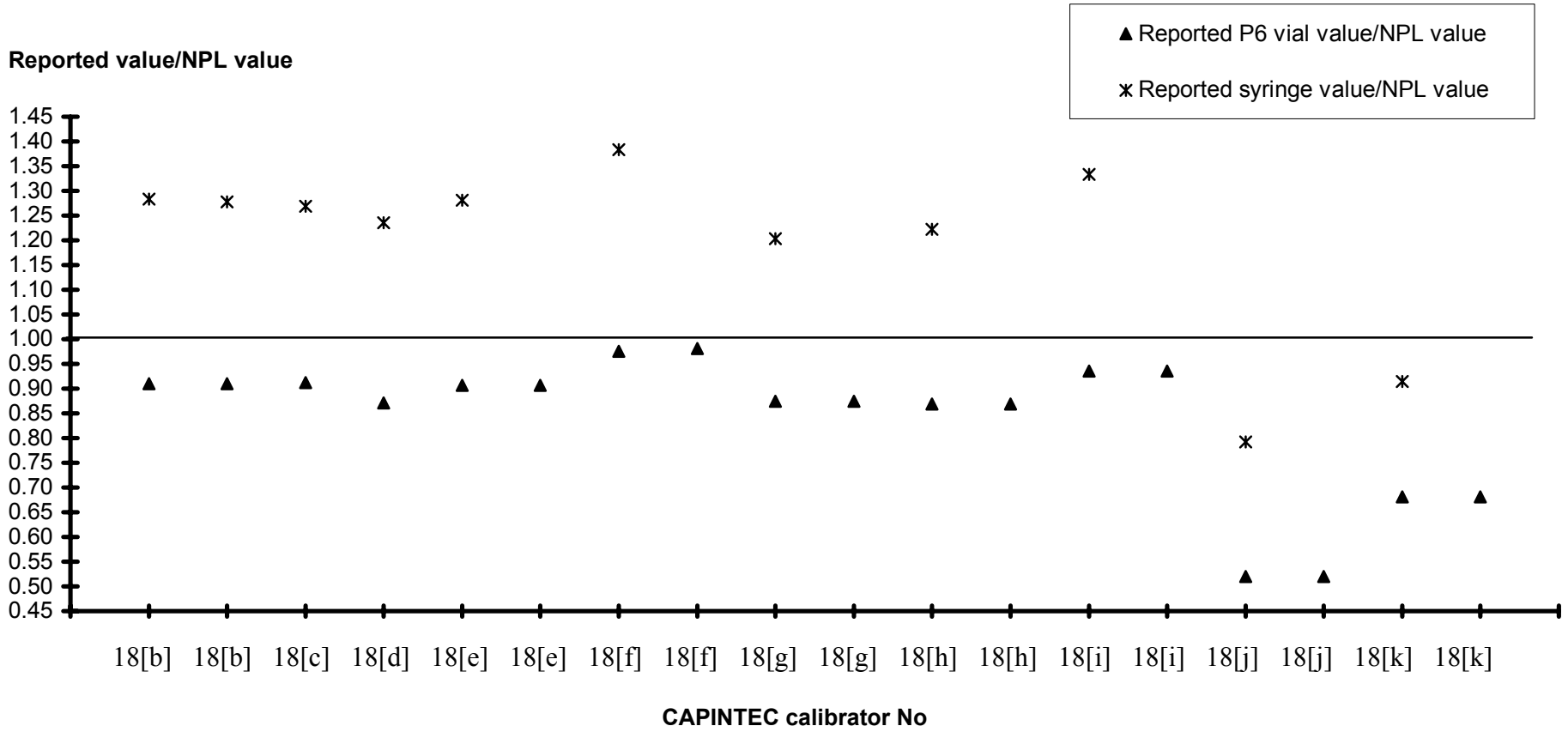


Figure 10 Distribution of P6 vial and syringe results from participant No 18



PARTICIPANTS

Participant	Hospital
J. MacDonald	Glan Clwyd Hospital, Wales
J R Ward	Royal Devon and Exeter, Devon
J Dickson	Medway Maritime Hospital, Kent
M L Wisbey	William Harvey Hospital, Kent
J Childs	Maidstone Hospital, Kent
A Aldous	Ipswich Hospital, Ipswich
P S Cosgriff	Pilgrim Hospital, Boston
M Evans	Royal Wolverhampton NHS
H Stockdale	Royal Liverpool University Hospital
R Wilks	Torbay Hospital, Torquay
R Honeybourne	Raigmore Hospital, Inverness
I Belton	Leicester Royal Infirmary
J McGarvie	Ayr Hospital
	Crosshouse Hospital, Kilmarnock
B Pratt	Royal Marsden NHS, Sutton
N Boyce	St Mary's Hospital, Portsmouth
R Gadd	North Staffordshire Hospital, Stoke-on-Trent
Robin Laney	Royal Cornwall Hospital, Truro
Rachel Smith	Guy's Hospital, London
Alex Hoffman	John Radcliffe Hospital, Oxford
	The Churchill Hospital, Oxford
	Royal Berkshire Hospital, Oxford
E A Harbottle	Gloucester Royal Hospital
Maria Tristam	Southampton General Hospital
P L Ormsby	Derriford Hospital, Plymouth
P Hillel	Royal Hallamshire Hospital, Sheffield
C Green	Northwick Park Hospital, Harrow
P Anderson	Queen Elizabeth Hospital, Birmingham
Martin Troy	The Childrens Hospital Birmingham
Eddy Rafiqi	Birmingham Heartland Hospital
M Fenwick	Ninewells Hospital, Dundee
W Johns	Hope Hospital, Salford
Peter Croasdale	Royal Free Hampstead NHS