

Brachytherapy, Diagnostic Radiology, Mammographic Radiology and
Ophthalmic Applicators: An assessment of current and future needs in the
UK and the role of NPL.

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ABSTRACT

Several UK hospitals were visited by NPL staff to discuss the current practises and future developments in brachytherapy, diagnostic and mammographic radiology and ophthalmic applicators. The results of the discussions are presented here, including NPL's role in each of these areas is discussed.

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ISSN 1369-6793

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1 INTRODUCTION

In order for the National Physical Laboratory to better understand the needs of the user community in the fields of brachytherapy, diagnostic radiology, mammographic radiology and ophthalmic applicators it was decided to visit a selection of hospitals throughout the United Kingdom. These visits were designed to discuss current practices and likely future developments in these areas of ionising radiation metrology. The results of these discussions will be used to contribute to the formulation of NPL's work programmes.

This report summarises the discussions between the authors and staff at the centres visited and the conclusions drawn from the information obtained.

2 BRACHYTHERAPY

Current practices

Most medical physicists in the UK follow the IPEM guidelines on brachytherapy dosimetry (ref.: BIR/IPSM working party, Recommendations for Brachytherapy Dosimetry, December 1992). This document covers both LDR and HDR measurements.

Low dose rate brachytherapy (LDR)

At present Cs-137 seeds, Ir-192 hair pins and coils and I-125 seeds are used in UK hospitals for LDR brachytherapy. However, it looks as if Cs-137 LDR and Ir-192 LDR work is moving to Ir-192 HDR work in this country. The source activity is usually measured with an NPL secondary standard radionuclide calibrator, previously known as Isocal IV, now known as NPL-CRC chamber. These results are compared to the manufacturers' figures and generally agree to $\pm 3\%$ and better with a quoted uncertainty of $\pm 5\%$.

I-125 seeds are of growing interest as they can be used for the treatment of early diagnosed cases of prostate cancer. The number of screening centres across the UK is increasing.

Instruments used for constancy checks are the SDS Nucletron well counter connected to a Farmer type electrometer, or a Standard Imaging HDR 1000 Plus well chamber connected to a CDX-2000A charge digitising electrometer. Some centres do not measure the activity of the I-125 prostate implant but rely on the manufacturer's value for source strength.

A new type of radionuclide that is likely to be introduced in the near future is Pd-103. Whether I-125 or Pd-103 sources are used, depends on how far the cancer has developed. However, the cost of Pd-103 is much higher than that of I-125, so it is currently not used that much.

High dose rate brachytherapy (HDR)

The two radionuclides that are most commonly used in high dose rate work are Co-60 and Ir-192. While Co-60 HDR treatment units seem to be phased out more and more hospitals are using Ir-192 HDR sources.

At present hospital physicists perform regular QA checks after each source change (every 3 months for Ir-192 HDR sources). They also perform source strength checks on a weekly or monthly basis. These results are compared to the manufacturers' figures and generally agree to $\pm 3\%$ with a quoted uncertainty of $\pm 5\%$.

Some hospital physicists use the Nucletron calibration jig to measure the source strength; others have built their own calibration jigs with a similar design. Various ionisation chambers and electrometers are used to carry out QA checks, e.g. Standard Imaging HDR 1000 Plus well chamber connected to a CDX-2000A charge digitizing electrometer, Keithley 35040 therapy dosimeter, PTW 0.3 cm³ thimble chamber type 23332 attached to PTW SN4 electrometer, PTW well chamber, Farmer 2571 thimble chamber. These ionisation chambers are either calibrated against a secondary standard chamber (e.g. NE 2561 thimble chamber) with a calibration traceable to the NPL primary standard or they are calibrated abroad (e.g. PTB (Germany), University of Wisconsin (USA)).

Endovascular brachytherapy

There are many different types of endovascular sources on the market that may or may not get approval in the UK in the next 5 to 10 years. Currently the one which a few hospitals are looking into is the Novoste Beta Cath. At the moment the only way to measure the Novoste Beta Cath source in a hospital is via radiochromic film to confirm the manufacturer's value. The Novoste Beta Cath system uses a Sr-90/Y-90 source which gives about 5mGy/s at 1 cm. The sources are calibrated using an extrapolation chamber but are hygroscopic and if left out in the air for any longer than about 2 hours will swell to a point where they will not fit down the catheter. These measurements have an uncertainty of about $\pm 5\%$.

The other main source currently in use is P-32 coated wire.

Equipment

Various brachytherapy afterloading units are in use throughout the UK, the principal ones being Nucletron's microSelectron 'Classic' and 'V2', Varian's 'Varisource' and MDS Nordion's 'Gammamed'.

The general view was that in future, apart from the trend to develop smaller sources, only the software side will change. No big change in the equipment design was expected.

2.2 The role of NPL at present

A calibration service for LDR Ir-192 wires and pins has been established at NPL for several years and the calibration service has been available.

At NPL, no calibration service for secondary standard thimble chambers needed for Ir-192 HDR measurements is currently available between the calibration point for heavily filtered 280 kV X-rays and the calibration point for Co-60 γ -rays. During our survey we found hospitals using either the 280 kV calibration point or a calibration factor based on an interpolation between the 280 kV X-ray calibration point and the Co-60 calibration point when performing Ir-192 high dose rate measurements.

2.3 The role of NPL in the future

An I-125 LDR calibration service will be available at NPL in a few months time and calibration factors will be published for the NPL secondary standard radionuclide calibrator (NPL-CRC chamber). NPL will also be looking at setting up a calibration service for Pd-103 sources. At this time it is not clear, whether a calibration service for balloon catheters and radioactive stents will be set up at NPL, as there are first signs that radioactive stents used for the treatment of endovascular diseases might be replaced by drug coated stents.

When asked which type of chamber hospitals would prefer NPL to calibrate for HDR dosimetry, there was no hesitation that the well type would be preferred due to the straightforward use of the chamber, the short measurement time and its good long-term stability. For the Standard Imaging well chamber, for instance, the average change in chamber response was found to be about $\pm 0.2\%$ per year. The type of measurement favoured would be $K_{\text{air}}/\text{Amp}$. Hospital physicists would be looking for an uncertainty of about $\pm 3\%$. It was pointed out the uncertainty NPL could achieve with a current measurement would not be as good as that with a charge measurement. A current measurement would still be preferred as this is easier for the hospital to perform.

2.4 Conclusions

Brachytherapy as a treatment modality is increasing in use in the UK and I-125 LDR seeds and Ir-192 HDR sources seem likely to remain popular.

At the hospitals visited it was felt that there was a need for a calibration service for Ir-192 HDR sources traceable to the UK national primary standard of air kerma.

With various brachytherapy units on the market, if using a well chamber as the preferred secondary standard chamber, different calibration factors will be required for different source geometries, e.g. Nucletron's microSelectron HDR 'Classic' and 'V2'.

Some hospital physicists are hoping for a measurement uncertainty of up to $\pm 1\%$, which would be very acceptable to clinicians.

3 DIAGNOSTIC AND MAMMOGRAPHIC RADIOLOGY.

3.1 Current practices

At present all the hospitals visited have a calibration traceable to the primary standard at PTB usually via a secondary standardising centre, either St. Georges Hospital or RRPPS Birmingham. Their diagnostic chambers are calibrated from about 50 kV to 150 kV and the mammographic chambers between about 20 kV and 35 kV.

The general impression is that if the chambers could be calibrated using clinical beams this would be an improvement over the current system where an industrial tube is used.

At present one protocol is used to calibrate diagnostic and mammographic instruments: this is outlined in the paper 'Calibration of Dosimeters used in Diagnostic Radiology' Scope Vol 1, No 4, Dec 92, pp44-48. The NPL calibration service is based on the IEC 1267 standard 'Medical Diagnostic X-ray Equipment-Radiation Conditions for use in the determination of characteristics'. This is not a calibration standard but details qualities that can be used for calibration purposes.

For mammography it is generally felt that tungsten targets are on the way out with rhodium on the increase and molybdenum being the most commonly used.

Internal calibrations of hospital tertiary standards are generally carried out on a yearly basis with the secondary standard being calibrated every three years.

At present a number of instruments are used as secondary standards by the hospitals. These range from Radcal 1015 to Keithley Triads and Unfors solid-state detectors.

The current uncertainty offered by the secondary standardising laboratory is of the order of $\pm 5\%$ with PTB offering an uncertainty of $\pm 2.7\%$. NPL should be able to match this uncertainty.

A diagnostic standard users group was felt to be a good idea although one suggestion was made that it should be led by the IPEM or NRPB rather than NPL and should cover a wider area than just metrology. All the hospitals visited thought that NPL would have a roll to play in such a forum. It was suggested that it should be brought up at the diagnostic special interest group.

A wide range of instruments are used by the hospitals for calibration, the principle ones being Radcal/MDH (1015, 2025 and variants) Keithley and PRM. A number of other types are also used, e.g. Unfors, PMX diode detectors and RTI solid state detectors.

Of the hospitals visited all use molybdenum tubes for mammography with rhodium filters being either used or introduced for larger breasts. Tungsten is still used in some places but this seems to be on the decline for mammography.

The hospitals view of what NPL's role in type testing might be was not altogether clear. NRPB was thought to be the best place for the type testing of most types of instruments in one case, but as far as solid state detectors were concerned at least one hospital thought NPL should do this as NPL could offer an impartial opinion on these as the calibrations offered by the manufactures were not as complete as they might have been. One hospital would value any opinion NPL might have on MosFet detectors.

There was a definite response in favour of the need for a calibration service for CT equipment. The hospitals visited all seemed to use a different technique for this area ranging from about 90 kV to 140 kV using 15 cc diagnostic chambers to 10 cm long sensitive volume chambers used in a phantom. Only part of the sensitive volume of this chamber is irradiated because a narrow beam is used; there is, however, a lot of scatter and low energy off-axis scatter. These chambers are not calibrated on arrival but are compared with Impact (this is an organisation set up by the DoH and has a similar function in the CT area to that of Kcare in the diagnostic field). Filtration varies from machine to machine and is of the 'bowtie type' ie. the shape of the filter is such that it is narrower in the middle than it is at the ends.

Most CT type of calibrations are done at two qualities these are about 125 kV with 2.5 mm Al + 0.1 mm Cu filtration (to give a HVL of 8.6 mm Al) and 1.5 mm Al + 1.0 mm Cu to give a HVL of 11.6 mm Al. The calibration factors are then applied down to about 90 kV.

Future

It was felt that there was likely to be an increase in low dose X-rays (such as dental) and in alternatives to X-rays such as MRI. With the Department of Health, at the time of writing, investing in new CT scanners there is clearly a demand for calibrations in this area of radiology. General-purpose machines will probably have more refined beam qualities (e.g. dual energy) but it is unlikely the current range of beam energies will be changed. Further areas where it was felt a calibration service would be useful are fluoroscopy, between 50 kV and 110 kV and 0.05 mA to 5 mA (with the possibility of up to 15 mA) and also in the dental area. There is no calibration service offered for this at the moment. Another area it was felt that NPL could make a contribution was performing checks on the solid state detectors used in auto kV and auto mA systems. These are on the increase and are set up at present by the installation engineers with no possibility of regular checks by the physicists. These devices are more energy dependent than chambers.

Conclusions

At the hospitals visited it was felt that there was a need for a calibration service traceable to the UK national primary standard of air kerma. This would mean that all

dosemeters used by hospitals, including therapy and protection dosimeters, are traceable to the same primary standards. The overall impression was that while NPL offer a service at present using constant potential industrial X-ray sets, the use of clinical sets would be preferred. As part of the NPL's previous programme a general diagnostic X-ray set and a mammographic X-ray set, typical of the types used in hospitals and clinics, have been installed at NPL. As part of the new programme a calibration service will be developed using these X-ray sets.

The protocol used is generally either the one quoted in Scope Vol 1, No4, Dec92, pp 44-48 'Calibration of Dosimeters used in Diagnostic Radiology', or the qualities and measurement techniques detailed in the international standard IEC 1267 'Medical Diagnostic X-ray Equipment- Radiation Conditions for use in the determination of characteristics'. The current NPL calibration service is based on the IEC 1267 qualities, although with the introduction at NPL of clinical sets it may be that we will have to adopt the other protocol if it is more appropriate for clinical sets.

In mammography the use of tungsten tubes is being phased out with molybdenum becoming the standard and rhodium being used more often for larger breasts. NPL at present can offer mammographic calibrations with molybdenum filters but not rhodium. The new clinical mammography unit installed at NPL includes both these filters.

The diagnostic standard users group was felt generally to be a good idea although it was felt that it should be wider ranging than just metrology and should cover a much wider field, e.g. imaging systems. It was felt that, while NPL had a role to play in such a group, it should perhaps be organised by somebody else such as the IPBM or NRPB. It should be a general forum for discussing any aspect of diagnostic radiology including problems and techniques.

There is a general feeling that NPL should be looking at providing calibrations in the field of CT especially in light of the fact that the Department of Health is currently increasing the number of CT scanners in hospitals. NPL is currently working to develop a calibration protocol for CT instruments by the end of its new programme (2004). However it was also felt that other areas of diagnostic radiology were not sufficiently well covered and that NPL should also think about offering calibrations in the fluoroscopic and dental areas.

It was also felt that NPL should be looking to widen the types of instruments we offer calibrations for to include solid-state detectors etc. There was also some interest in NPL doing type testing, in particular, of solid state and MosFet type detectors.

The main concerns about the current NPL calibration service are the length of time the instruments are at NPL, the cost of the calibration and the fact that the service is inflexible i.e. that it is a batch system held at a particular time of year.

4 OPTHALMIC APPLICATORS

4.1 Current practices

At present, the use of ophthalmic applicators is limited: not all hospitals own them and those that do use them infrequently (a few times per year). The Sr-90 applicators in the hospitals have generally been in use for many years and are mostly of the curved variety. The half-life of Sr-90 (nearly 30 years) ensures a long working life for the applicators. The manufacturer's certificate issued with the applicator and the well-known value of the half-life are used to calculate the treatment dose. The uncertainty quoted in the certificates is of the order of $\pm 30\%$ or higher at the 2σ level. However, several hospitals over the past few years have expressed an interest in having the curved applicators calibrated at NPL.

4.2 Future needs

Quality assurance has become increasingly important in recent years and the regular measurement or calibration of applicators should be part of this process. The use of curved applicators containing Ru-106 instead of Sr-90 as the radioactive element is becoming more common (the higher energy of the β -rays emitted by Ru-106 allow more effective treatment). The half-life of Ru-106 (approximately 6 years) is considerably shorter than Sr-90 so a quicker turnover of applicators is likely.

4.3 The role of NPL: present

The primary standard for the measurement of planar ophthalmic applicators (Sr-90 and Ru-106) has been established for a number of years and the calibration service has been available. The uncertainty quoted by NPL is approximately $\pm 10\%$ at the 2σ level.

4.4 The role of NPL: future

The calibration of curved applicators traceable to the primary standard via a transfer method (chemical dosimetry using thin alanine pellets) has proved to be robust and the launch of the NPL calibration service for curved applicators is scheduled for 2002. The uncertainty associated with this type of calibration is expected to be approximately $\pm 20\%$. Several enquiries have already been received from hospitals asking for a calibration of curved Sr-90 applicators. It is unlikely that the nature of the calibration service offered by NPL will change significantly for the foreseeable future.

4.5 Conclusions

The lower uncertainties achieved at NPL in the calibration of ophthalmic applicators compared to those of the manufacturers, the growing emphasis on quality assurance in the clinical environment, the use of Ru-106 and the ability to calibrate curved applicators at NPL are all expected to lead to an increase in the number of hospitals seeking NPL calibrations for their applicators.

5 Acknowledgements

The authors would like to thank staff at the following institutions for their assistance in the production of this report:

Medical Physics Department, Royal Devon and Exeter Healthcare NHS Trust, Exeter.

Medical Physics Department, Churchill Hospital, Oxford.

Medical Physics Department, Cookridge Hospital, Leeds.

Regional Medical Physics Department, Newcastle General Hospital, Newcastle Upon Tyne.

The Radiological Protection Centre, St. Georges Hospital, Tooting.

Radiological protection Service, Royal Surrey County Hospital, Guildford.