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Establishing Traceability for Radiotherapy Dose Calibration in Ukraine

Serhii Brovchuk, PhD[1,2], Oleg Vaskevych, MSc[3], Oleksandr Filatov, PhD[4], Vyacheslav Lizunov, PhD[4], Ruslan Zelinskyi[5], **Viktor M. Iakovenko, PhD[6]**, Natalka Suchowerska, PhD[7], Anna Ralston, MSc[8], Nataliya Kovalchuk, PhD[9], Graham Bass, MSc[10], Russell Thomas, PhD[10] and Catharine H Clark, PhD[10]

[1]LISOD - Israeli Oncology Hospital, Pliuty, Kyiv Region, Ukraine, [2]O.O. Shalimov National Scientific Center of Surgery and Transplantation, Ukraine, [3]Kyiv Regional Oncology Dispensary, Kyiv, Ukraine, [4]G. V. Kurdyumov Institute for Metal Physics of the N.A.S. of Ukraine, Kyiv, Ukraine, [5]National Cancer Institute, Kyiv, Ukraine, [6]The University of Texas Southwestern Medical Center, Dallas, TX, USA, [7]School of Physics, The University of Sydney, Sydney, Australia, [8]St George Hospital Cancer Care Centre, Kogarah, Australia, [9]Department of Radiation Oncology, Stanford University, Stanford, CA, USA, [10]Metrology for Medical Physics, National Physical Laboratory, Teddington, United Kingdom

ABSTRACT

Ukraine is modernizing radiotherapy rapidly despite having no operational national Secondary Standard Dosimetry Laboratory (SSDL) to anchor dose calibration.
This project provides interim international traceability for absorbed dose to water by performing cross-calibration in Ukraine against chambers calibrated at Primary Standards Dosimetry Laboratories abroad. Its goal is to ensure every Ukrainian clinical medical physicist can rely on an ionization chamber that is traceable to a primary standard and verified to perform correctly — the first practical step toward establishing a national SSDL.

INTRODUCTION

- **Between 2023 and 2025, Ukraine installed 24 new linear accelerators to replace ageing cobalt-60 units — 68 of the country's 96 megavoltage treatment units are now linacs.**
- **Linacs offer clinical advantages, but require rigorous dosimetric control to ensure dose accuracy and stability.**
- **Without a national SSDL, traceability has relied largely on vendor calibration certificates, with no unified national pathway to a primary standard.**
- **To close this gap without sending a single chamber abroad, an international team of clinical physicists, metrology specialists, and academic experts was formed.**

CONTACT

Serhii Brovchuk
LISOD Israeli Oncology Hospital, Pliuty, Kyiv Region, Ukraine
O.O. Shalimov National Scientific Center of Surgery and Transplantation, Kyiv, Ukraine
brovchuksm@gmail.com

METHODS AND MATERIALS

- An international working group of physicists from Ukraine, the UK, Australia, and the United States was formed. With guidance from the National Physical Laboratory and support from the Help Ukraine Group, a cross-calibration workflow and methodology were developed (Diagram 1).
- Using donated equipment (**ARPANSA-calibrated** Exradin A19 chamber with SuperMAX electrometer, a motorized 1D water tank (Icon Group Australia), Scientific thermometer, and barometer (Future Ukraine Ltd Australia) and **NPL-calibrated** PTW 30013 Farmer chamber, a complete travelling dosimetry kit was assembled (Figure 1).
- Cross-calibration was performed in an Elekta Versa HD and Varian Clinac 6 MV beam (Figure 2) in Kyiv, Ukraine; beam quality $TPR_{20,10}$ was measured and compared with the nominal data.
- $N_{D,w}$ was measured for four Ukrainian chambers and one ARPANSA-calibrated chamber, then compared with the chamber certificate values dated 2020-2021.

United Kingdom
National Physical Laboratory (NPL), PSDL

Support: reference calibration, dosimetry expertise, methodology, supervision

Australia
University of Sydney, St. George Hospital

Support: ARPANSA-calibrated chamber, electrometer, phantoms, reference-class thermometer and barometer, clinical expertise, methodology

United States of America
UT Southwestern Medical Center
Stanford University

Support: workflow, clinical medical physics expertise.

Ukraine
LISOD Israeli Oncology Hospital; Kyiv Regional Oncology Dispensary; National Cancer Institute, Kurdyumov Institute for Metal Physics of N.A.S of Ukraine

Cross-calibration on a clinical linear accelerator in Kyiv, Ukraine
Result: Tested chambers traceable to the primary standard of absorbed dose-to-water without sending equipment abroad

Diagram 1. Working group of physicist from medical and academic international institutions

Figure 1. Traveling dosimetry kit assembled from donated equipment.

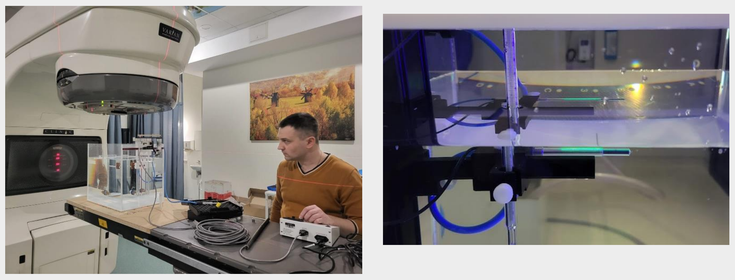

Figure 2. Cross-calibration in 6MV beam at reference depth.

RESULTS

During design and implementation of the cross-calibration procedure, four Ukrainian chambers were tested, with an ARPANSA-calibrated chamber used for independent cross-check. Beam quality $TPR_{20,10}$ was measured and confirmed to match nominal data. The absorbed dose-to-water coefficient $N_{D,w}$ was determined for each chamber and compared with certificate values, with percentage differences ranging from 0.04% to 0.50% (Table 1).

Table 1. Comparison of calibration coefficients $N_{D,w}$: calibration certificates vs cross-calibration

Ion Chamber	TPR^{20}_{10} (nominal)	TPR^{20}_{10} (measured)	$N_{D,w}$ (certificate) x10^7 (Gy/C)	$N_{D,w}$ (measured) x10^7 (Gy/C)	Uncertainty (certificate),%	$\frac{N_{D,w}(measured)-N_{D,w}(certificate)}{N_{D,w}(measured)}$, %
1Ukr	0.680	0.679	5.085	5.087	1.3	0.04
2Ukr		0.680	5.090	5.084	1.3	0.12
3Ukr		0.678	4.748	4.725	2.2	0.50
4Ukr		0.679	28.109	28.219	1.3	0.40
5Aus		0.680	4.853	4.860	0.9	0.14

CLINICAL IMPACT

Reference-dosimetry uncertainties can stem from calibration methods, staff proficiency, and equipment performance. At this initial stage, the project focuses on addressing the equipment-related component.

What is the clinical impact of this work?

- ✓ Verification that clinical calibration coefficients remain stable and correct without shipping chambers abroad.
- ✓ A documented chain to the UK primary standard of absorbed dose-to-water.
- ✓ An independent cross-check via an ARPANSA-calibrated chamber.
- ✓ Peer review of local dosimetry protocols, measurement practice, and equipment with international colleagues.

Finally, end-user assurance is achieved: each chamber is not only calibrated, but traceable, independently checked, and ready for clinical reference dosimetry.

This is an important step towards assuring the patient dose is accurate, safe, and consistent — no matter where in Ukraine they receive radiotherapy.

CONCLUSIONS

- ✓ International collaboration can maintain accurate, traceable dosimetry even in wartime conditions.
- ✓ The working group has delivered the technical, scientific, and clinical foundations for a future Ukrainian SSDL — and this project represents the first operational step toward this goal.

Outlook — next steps:

- ✓ Integrate cross-calibration service into Ukrainian dosimetry infrastructure.
- ✓ Finalize uncertainty budget evaluation.
- ✓ Perform cross-calibration for 10 regional cancer centers and invite national radiotherapy centers to regional cross-calibration sessions across Ukraine.
- ✓ Build staff capacity and infrastructure for a future dosimetry laboratory based on the platform at National Academy of Sciences of Ukrainian.

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