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TOPICAL DEBATE

Golden beam data provided by linear accelerator manufacturers should be used in the commissioning of treatment planning systems

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Introduction and overview: Clive Baldock, moderator

In radiation therapy, dosimetry accuracy is an important factor which if compromised has the potential to impact acceptable clinical treatment outcomes. Dosimetry accuracy is affected not only by the quality of a linear accelerator's (linac's) commissioned radiation beam, but also on how well the commissioned linac radiation beam can be maintained to achieve the same or similar radiation characteristics as at commissioning time of the linac.

In this topical debate, Yousif Yousif and Jerome Gastaldo debate whether so-called golden beam data (GBD) provided by linac manufacturers should be used in the commissioning of treatment planning systems.[1]

Arguing for the proposition is Yousif A. M. Yousif. Dr Yousif is currently a medical physics specialist at the North West Cancer Centre in Tamworth, Australia. Yousif earned his BSc in Applied Physics from Al-Neelain University, Sudan and his MSc (2007) and PhD (2012) from the University of the Free State and the University of Pretoria, South Africa, respectively. His research project was focused on the development and validation of a quality assurance (QA) program for modulated radiotherapy techniques. He is a certified Radiation Oncology Medical Physicist by the Health Professions Council of South Africa (HPCSA) and the Australasian College of Physical Scientists & Engineers in Medicine (ACPSEM). Yousif has more than 10 years of experience as a clinical medical physicist. He has worked as a lecturer in Sudan and South Africa, as well as a clinical physicist at several radiation oncology institutions in South Africa before migrating to Australia in 2014. In Australia, before joining the North West Cancer Centre, he took a lead role at the Radiation Oncology Centre (ROC) Maroochydore (formally Oceania Oncology Sunshine Coast, Queensland). In his current role, he oversees the clinical services and is actively involved in education, training, and clinical research. His research interest is in developing and implementing advanced radiotherapy techniques to improve patients' treatment outcome, particularly in regional settings, patient-specific QA and dosimetry, and Monte Carlo simulation techniques in radiotherapy. He is a member of the ACPSEM NSW/ACT branch executive committee. In recent years, he co-founded the Regional Collaboration Initiative (RCI) group to support medical physics training and education, and professional aspects in regional centres and actively participating with the ACPSEM project in regionalizing training for supporting regional radiotherapy centres.

Yousif Yousif

[1] Contributors to Topical Debates are selected for their knowledge and expertise. Their position for or against a proposition may or may not reflect their personal opinions.

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Arguing against the proposition is Jerome Gastaldo. Dr Jerome Gastaldo is currently the chief physicist at St Georges Cancer Care Centre in Christchurch New Zealand. Jerome was introduced to medical physics during his master's degree internships at McMaster University in Hamilton, Ontario, Canada and at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France under the supervisions of David Chettle and Elke Brauer Krisch respectively. Following this initiation, Jerome trained as a clinical medical physicist in France, qualifying in 2004. He then studied for his PhD at ESRF where he worked on radiobiology and the applications of synchrotrons in the medical field. Jerome moved to the Canterbury District Health Board in Christchurch, New Zealand in 2008. 2 years later he joined the brand-new Cancer Care Centre at St Georges hospital in Christchurch. Throughout his career Jerome has worked on a broad range of equipment: Linacs from the 3 major vendors Varian, Elekta and Siemens, Cobalt treatment units, a variety of kilovoltage therapy units and a synchrotron. Since 2020 he has been involved in the implementation of the first New Zealand MR-Linac which is expected to be delivered to St Georges Cancer Care Centre in 2022. In addition to his main clinical activity, Jerome is also a member of several committees. He is committed to the training of medical physicist and is part of the Radiation Oncology Certification Panel (ROCP) committee and the Clinical Training Guide (CTG) review lead group. He is also a member of the Trans Tasman Radiation Oncology Group (TROG) MR and Adaptive Sub-Committee.

Jerome Gastaldo

Opening Statement – Yousif Yousif

Radiotherapy treatment outcomes rely on the dose delivered to the patient, which depends on the accuracy of the linac's acquired beam data used in the commissioning of the treatment planning system (TPS). Generally, TPS commissioning is a tedious, time-consuming task and requires more personnel and instrumentation [1], and thus errors may be introduced during any of the above processes. Therefore, one of the proposed approaches to reduce potential errors and shorten the commissioning time without compromising the accuracy and quality of acquired data is to use the manufacturer's GBD [2, 3].

With advances in technology, manufacturers have been producing standardized linacs with reliable and accurate beams for clinical use. The majority of the manufacturers provide GBD for a specific linac model [4]. Therefore, I believe that GBD provided by the manufacturers should be used in the commissioning of TPSs for several reasons.

First, errors introduced during data acquisition and processing will be systematic and propagate through to having impact on all patients. The World Health Organization (WHO) reported that about 24% of radiotherapy's adverse events are related to the TPS commissioning [4]. Recently, the Imaging and Radiation Oncology Core (IROC) conducted a credentialing study and found that 17% of institutions demonstrated dose calculation errors which could possibly have been related to errors in the TPS beam modelling and validation [5].

Second, some studies have confirmed that the locally acquired beam data are either equivalent within 1% to that provided by the manufacturer [6, 7] or to beam data for linacs of the same model [8, 9]. Glide-Hurst et al. [6] reported excellent agreement between five Varian TrueBeam data from three institutions. Similar findings have been reported by Tanka et al. [7]. A recent study has shown that the average calculated data for a number of Varian C-series linacs from 20 institutions can be used as reference beam data for TPS commissioning verification [8].

Third, a survey study amongst the medical physics community revealed large variations in determining the optimal values of beam modelling parameters such as dosimetric leaf gap (DLG), multileaf collimator (MLC) transmission, effective spot size, and flattening filter Gaussian width [10]. Glenn et al. [11] investigated the dosimetric impact of several dosimetric and beam modelling parameters based on community-driven data from the IROC's site visit. The results highlighted a significant disagreement in dose distributions compared to one using the baseline beam model, which should be of concern to the community.

Finally, TPS commissioning is an enormous task and requires far more personnel and resources than is available in most facilities, particularly within smaller or limited-resourced hospitals and clinics [1]. So, the use of the GBD could simplify the commissioning work without jeopardising the quality.

In summary, the GBD provided by the manufacturer is a beneficial resource, is already installed into the TPS and so not requiring data transfer and, will therefore assist in avoiding data misadministration. If used effectively, it would help to improve patient safety, efficiency, dosimetric accuracy, achieve consistency among the medical physics community,

and help to simplify the commissioning processes, particularly in limited-resource settings.

Opening Statement – Jerome Gastaldo

GBD have been available for many years [12] and the use of this data was the topic of a Point/Counterpoint article published in Medical Physics in 2012 [13]. Many of the published arguments still apply.

Over the past decade, treatment complexity has increased with tighter margins, the widespread use of volumetric modulated arc therapy (VMAT) techniques involving smaller field segments, and the current trend towards more hypofractionated treatments. Stereotactic ablative radiotherapy (SABR) is a perfect illustration of these more demanding objectives.

The ability to deliver these complex treatments relies on the accuracy of the TPS and the quality of the beam model used. Any discrepancy between the TPS model and the treatment unit could have dramatic impact.

Historically, models have been developed to match commissioning measurements. The use of GBD represents the opposite approach, whereby the user adjusts the linac in accordance with the vendor beam model. The GBD is produced by averaging the data obtained over a range of machines from around the world. This presents a potential first drawback, in that matching a linac to an average machine does not guarantee optimized performance. As medical physicists, are we happy to be aiming for the average outcome, or should we aim to produce the best result?

Secondly, beam-matching to vendor data has been shown to be a valid approach for large field sizes, but caution needs to be exercised when dealing with more complex and demanding techniques. Tanaka et al. [14] compared beam data for 21 TrueBeams and showed good agreement for field sizes $\geq 100 \times 100$ mm^2. They also demonstrated dose differences larger than 2% for the off-centre ratio for a 30×30 mm^2 field size.

Many would argue that using the GBD speeds up the linac commissioning process which is most likely achieved by acquiring a subset of data during the commissioning. However, the commissioning process offers a unique opportunity to develop a deep knowledge of the linac. Shortening this may impact the medical physicists' overall understanding of the linac behaviour and make future troubleshooting much more difficult. More importantly, and as mentioned in the American Association of Physicists in Medicine (AAPM) TG-106 report [8], performing a series of spot checks to validate the match can be dangerous as it could potentially prevent the detection of discrepancies between the GBD and the experimental reality. It is not enough to rely only on the vendor beam-matching criteria, and very strict criteria needs to be implemented to obtain a satisfactory match. This has been shown by several authors [15–17].

The time and effort required to match a linac to GBD is still significant. In light of this, time may be better invested in creating a personalised, optimal model based on comprehensive commissioning of the machine. This has been shown as the best approach by Hansen et al. [18] who compared a clinical model, a Raystation model and a hybrid IROC-Raystation model.

Rebuttal – Yousif Yousif

My esteemed colleague has made a number of excellent points, but the question we need to ask is: is this truly where we want to spend our time at work?

An experienced radiotherapy physicist may complete the conventional commissioning process of a TPS in 6–8 weeks [19]. The adoption of GBD will result in a significant reduction in amount of time and resources required. This is particularly significant in resource-constrained contexts such as smaller departments in rural locations. Additionally, the literature suggests that utilising GBD could considerably improve QA and that patient-specific quality assurance (PSQA) of the Radiological Physics Center (RPC) tests results in greater pass rates [20].

The use of pre-configured beam data for TPS commissioning is a recent trend in radiotherapy. All O-ring gantry linac systems (i.e. Halcyon and Ethos) come with pre-configured beam data. As a result, medical physicists have available small sets of verification measurements [21]. This saves them a lot of time, rather than having to undertake water tank scanning over many days with the potential of making mistakes, especially in smaller centres with fewer physicists involved. As a result, medical physicists may spend time understanding and designing QA processes for these automated systems and technologies. Medical physicists have to work long and often irregular hours, so why not make their lives easier by employing the GBD? When compared to the past, this improves work-life balance in busy departments.

The field is gradually moving away from measurements and towards automation. For example, QA analysis is carried out using systems such as DoseLab (Varian), while PSQA can be carried out using Mobius 3D with higher specificity than measurements.

COVID-19 has brought unprecedented challenges in health care in which staff and resources were compromised with workload and quality changed. Therefore, GBD is an example of how it could be employed for commissioning without compromising the quality. The use of GBD will

provide consistency in beam data which is helpful in clinical trials resulting in standardisation of clinical trial plans.

Finally, what is the clinical gain of using measured data? If one could compare the radiobiological impact, what would it be? But to do that properly, you would need to actually do a clinical trial with and without, which will be very challenging. The uncertainties of the biological outcome of treatment is likely to be much larger inherently than choosing between using GBD.

In conclusion, I feel the GBD is a wonderful resource that helps the TPS commissioning process run smoothly and accurately. As a result, our responsibility as medical physicists is to understand these systems, particularly if we lack formal training in using these systems, rather than spending days measuring data for only limited gain.

Rebuttal – Jerome Gastaldo

My esteemed colleague has some very good points regarding the benefits of the GBD, however they do not completely justify a generalised deployment of the GBD.

It is important to note that the vast majority of the publications focusing on GBD use Varian linacs which does not reflect the market share. Peer reviewed literature is lacking for other vendors.

There is much to be gained by using local data for the beam model as mentioned in my opening statement. The iROC study [11] cited by my colleague highlighted some concerning results linked to suboptimal modelling but they also mentioned an abundant number of cases where using the GBD reduced the accuracy of the beam model, a result unacceptable for modern beam delivery techniques.

The limitations of the GBD have been illustrated by Sjostrom et al. [22] who showed that it is not always possible to match linacs and some specific models might be required. Similarly, McLauglin et al. [16] demonstrated some electron energy spectral differences when comparing six matched Linacs.

Finally, the accuracy of the TPS beam model is critical for patient safety as indicated by my esteemed colleague. It is also true that the collection of the beam data is a very resource consuming task. However, it is perilous to take any potential shortcut and the lessons learned from previous accidents should mandate deploying the appropriate resources to perform such a critical task especially when dealing with more advanced technologies and techniques.

To conclude, I fully agree that the manufacturer GBD are beneficial and should be used. However instead of using them to create the TPS beam model they should only be used as a starting point for a personalized model or to check that the local data are not completely erroneous. In addition, using external audit services such as the one offered by the Australian Clinical Dosimetry Service (ACDS) or IROC should also be encouraged as part of best practice.

References

1. Yousif Y, McKinnon S, Hsieh W-L et al (2020) O184 Establishing a TPS QA program based on AAPM Medical Physics Practice Guideline (MPPG 5.a.). Phys Eng Sci Med 43:404
2. Das IJ, Njeh CF, Orton CG (2012) Point/counterpoint: vendor provided machine data should never be used as a substitute for fully commissioning a linear accelerator. Med Phys 39:569–572
3. Varian Medical System (2015) TrueBeam Representative Beam Data for Eclipse. https://www.myvarian.com/s/productdocumentation?lang=en. Accessed 1 February 2022
4. World Health Organization (2008) Radiotherapy Risk Profile Technical Manual (WHO/IER/PSP/2008.12). https://www.yumpu.com/en/document/read/11250974/radiotherapy-risk-profile-world-health-organization. Accessed 1 February 2022
5. Kerns JR, Stingo F, Followill DS (2017))Treatment Planning System Calculation Errors Are Present in Most Imaging and Radiation Oncology Core-Houston Phantom Failures. Int J Radiat Oncol Biol Phys 98:1197–1203
6. Glide-Hurst C, Bellon M, Foster R et al (2013) Commissioning of the Varian TrueBeam linear accelerator: a multi-institutional study. Med Phys 40:031719
7. Tanaka Y, Mizuno H, Akino Y et al (2019) Do the representative beam data for TrueBeam™ linear accelerators represent average data? J Appl Clin Med Phys 20:51–62
8. Tanaka Y, Mizuno H, Akino Y et al (2020) Collection and analysis of photon beam data for Varian C-series linear accelerators: a potential reference beam data set. Phys Eng Sci Med 43:889–901
9. Ghazal M, Södergren L, Westermark M (2020) Dosimetric and mechanical equivalency of Varian TrueBeam linear accelerators. J Appl Clin Med Phys 21:43–53
10. Glenn MC, Peterson CB, Followill DS et al (2020) Reference dataset of users' photon beam modeling parameters for the Eclipse, Pinnacle, and RayStation treatment planning systems. Med Phys 47:282–288
11. Glenn MC, Peterson CB, Howell RM et al (2020) Sensitivity of IROC phantom performance to radiotherapy treatment planning system beam modelling parameters based on community-driven data. Med Phys 47:5250–5259
12. Breitman K, Rathee S, Newcomb C et al (2007) Experimental validation of the Eclipse AAA algorithm. J Appl Clin Med Phys 8:76–92
13. Das IJ, Njeh CF, Orton CG (2012) Vendor provided machine data should never be used as a substitute for fully commissioning a linear accelerator. Med Phys 39:569–572
14. Das IJ, Cheng CW, Watts RJ et al (2008) Accelerator beam data commissioning equipment and procedures: Report of the TG-106 of the Therapy Physics Committee of the AAPM. Med Phys 35:4186–4215
15. Sjöström D, Bjelkengren U, Ottosson W et al (2009) A beam-matching concept for medical linear accelerators. Acta Oncol 48:192–200
16. Rijken J, Schachenmayr H, Crowe S et al (2019) Distributive quality assurance and delivery of stereotactic ablative radiotherapy treatments amongst beam matched linear accelerators: A feasibility study. J Appl Clin Med Phys 20:99–105
17. Gershkevitsh E, Peraticos A, Dimitriadis Raad D et al (2010) SU-GG-T-306: can single dataset in treatment planning

system represent several beam-matched. accelerators? Med Phys 37:3256–3256
18. Hansen JB, Frigo SP (2021) Evaluation of candidate template beam models for a matched TrueBeam treatment delivery system. J Appl Clin Med Phys 22:92–103
19. Smilowitz JB, Das IJ, Feygelman V, AAPM Medical Physics Practice Guideline Task Group (2015) Commissioning and QA of Treatment Planning Dose Calculations - Megavoltage Photon and Electron Beams. J Appl Clin Med Phys 16:14–34AAPM Medical Physics Practice Guideline 5.a.
20. Molineu A, Hernandez N, Nguyen T et al (2013) Credentialing results from IMRT irradiations of an anthropomorphic head and neck phantom. Med Phys 40:022101
21. Gao S, Netherton T, Chetvertkov MA et al (2019) Acceptance and verification of the Halcyon-Eclipse linear accelerator-treatment planning system without 3D water scanning system. J Appl Clin Med Phys 20:111–117
22. McLaughlin DJ, Hogstrom KR, Neck DW et al (2018) Comparison of measured electron energy spectra for six matched, radiotherapy accelerators. J Appl Clin Med Phys 19:183–192

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