Australian Government
Australian Research Council

EI 2018 ENGAGEMENT AND IMPACT

Engagement and Impact 2018

Queensland University of Technology

QUT02 (ST) - Impact

Overview

Title

(Title of the impact study)

Improving treatments for cancer patients through a better understanding of the physics of radiation beams

Unit of Assessment

02 - Physical Sciences

Additional FoR codes

(Identify up to two additional two-digit FoRs that relate to the overall content of the impact study.)

11 - Medical and Health Sciences

Socio-Economic Objective (SEO) Codes

(Choose from the list of two-digit SEO codes that are relevant to the impact study.)

92 - Health

Australian and New Zealand Standard Industrial Classification (ANZSIC) Codes

(Choose from the list of two-digit ANZSIC codes that are relevant to the impact study.)

84 - Hospitals
85 - Medical and Other Health Care Services

Keywords

(List up to 10 keywords related to the impact described in Part A.)

Radiation therapy

Radiation detection

Linear accelerator

Radiation dose

Treatment planning

Sensitivities

Commercially sensitive

No

Culturally sensitive

No

Sensitivities description

(Please describe any sensitivities in relation to the impact study that need to be considered, including any particular instructions for ARC staff or assessors, or for the impact study to be made publicly available after EI 2018.)

Aboriginal and Torres Strait Islander research flag

*(Is this impact study associated with Aboriginal and Torres Strait Islander content?
NOTE - institutions may identify impact studies where the impact, associated research and/or approach to impact relates to Aboriginal and Torres Strait Islander peoples, nations, communities, language, place, culture and knowledges and/or is undertaken with Aboriginal and Torres Strait Islander peoples, nations, and/or communities.)*

No

Science and Research Priorities

(Does this impact study fall within one or more of the Science and Research Priorities?)

No

Impact

Summary of the impact

(Briefly describe the specific impact in simple, clear English. This will enable the general community to understand the impact of the research.)

Recent technological advances have allowed radiation therapy, a critical component in cancer treatment, to diagnose and treat smaller, earlier stage, and more complex tumours. However, understanding how the delivery of narrower, high resolution radiation beams behave within patients and how they can be focused on the tumour when a patient moves, such as breathing, has been a challenge. QUT researchers have solved a number of these delivery and targeting issues for small radiotherapy beams. The significant impact of this work is reflected in the adoption of the research outcomes into international cancer treatment protocols, including standards published by agencies such as the International Atomic Energy Agency and the International Commission on Radiation Units & Measurements.

Beneficiaries

(List up to 10 beneficiaries related to the impact study)

Cancer patients will benefit from improved and more accurate treatments

Cancer treatment specialist centres (including research centres)

Agencies responsible for radiation protocol in patients

Medical professionals – Radiologists, Oncologist

Health system: reduced costs via an increased probability of treatment success with higher cancer survival rates

Countries in which the impact occurred

(Search the list of countries and add as many as relate to the location of the impact)

Australia
United States of America
Canada
England
Scotland
Ireland
Netherlands

Details of the impact

(Provide a narrative that clearly outlines the research impact. The narrative should explain the relationship between the associated research and the impact. It should also identify the contribution the research has made beyond

academia, including:
- who or what has benefitted from the results of the research (this should identify relevant research end-users, or beneficiaries from industry, the community, government, wider public etc.)
- the nature or type of impact and how the research made a social, economic, cultural, and/or environmental impact
- the extent of the impact (with specific references to appropriate evidence, such as cost-benefit-analysis, quantity of those affected, reported benefits etc.)
- the dates and time period in which the impact occurred.

NOTE - the narrative must describe only impact that has occurred within the reference period, and must not make aspirational claims.)

In 2014, 123,920 new cases of cancer were diagnosed in Australia alone and the increase in incidences of cancer is predicted to rise by 3% annually over the next 10 years. A significant number of cancer patients will receive treatment with ionising radiation, known as radiotherapy, where the primary goal is to deliver a lethal dose of radiation to the tumour only, whilst minimising the dose to surrounding healthy tissue. This has proved problematic in instances of radiotherapy treatment of small and earlier-stage tumours due to issues such as patient (and tumour) movement while breathing. QUT's Radiotherapy research team, is one of the few international research groups, focussing on solving this problem for small field radiotherapy. The QUT group comprises academic physicists and practising registered medical physicists who have adjunct appointments or are completing their PhD at QUT, while also working in Australian hospitals/cancer centres. The importance and relevance of the QUT team, which also has strong collaborations with other working medical physicists across Australia, is their work on understanding and developing solutions to real-life problems encountered in their professional, clinical settings. The team has provided multiple novel outcomes, in both small field and general radiotherapy, which have been widely reported in the literature and incorporated into clinical practice, treatment guidelines, both in Australia and internationally.

Small field radiotherapy concerns radiotherapy beams below 1.5 cm in width – a size for which beam characterisation and measurement is problematic and inhibits treatment of many early-stage cancers. QUT's theoretical and experimental research over the period 2011-2016 has resulted, for the first time, in a physical definition of a small beam based on its theoretical and practical characteristics enabling radiotherapy departments to halve the size of standard radiotherapy beams from the previous 3 cm to 1.5 cm before beams are considered small and require special 'small field' corrections to be made in planning a patient's treatment. This means that the radiotherapy being delivered has much better results in only targeting the tumour and not the healthy tissue or nerves and also accommodates patient movement during the treatment, while still producing a reliable dose of ionising radiation for the patient.

In this area of medicine, protocols are developed and shared amongst other physicists through academic journal articles and international practitioner journals. This research on small field radiotherapy was published in 2014 [1] and was on the 'most accessed' list of the journal Medical Physics for several months, evidencing the impact and interest as the information was fed into clinical practice internationally.

A further benefit of this small field radiotherapy research was that researchers in examining radiation treatment doses which are based on measurements made in water, found that very small air bubbles in the path of a small beam can alter the downstream radiation dose by up to 25% and thereby could drastically alter a patient's treatment [2]. This observation led to a further innovative development, whereby radiation detectors used for conventional radiotherapy beams (and which over-respond for small fields) can be 'tuned' for small fields by deliberately introducing an air pocket. This modification is highly applicable to clinical practice where radiotherapy cancer centres must verify their beam outputs on a regular basis and require reliable measurement techniques.

A key factor in small field radiotherapy treatment also arises due to differences in output of the various linear accelerators and sensitivities of detectors in worldwide use. Our research has both highlighted this important problem and provided and applied correction methodologies for clinical use [3-6]. The outcomes have been recognised internationally demonstrated by their incorporation into international and national guidelines which set cancer treatment protocols worldwide, eg the IAEA TRS483 'An International Code of Practice for Reference & Relative Dose Determination'; ICRU91 'Prescribing, Recording, & Reporting of Stereotactic Treatments with Small Photon Beams'; Netherlands National Guideline for Cranial Stereotactic Radiosurgery. QUT's published papers on small field radiotherapy in the assessment period have been cited in papers published by 157 institutions, 123 of these were cancer care centres and government regulators (Source: Scopus), which is indicative of the real world use of the research, given that research in this field is predominantly clinically driven.

The research team also contributed new algorithms to the field of general radiotherapy which provide higher levels of quality assurance and significant time savings. As radiotherapy treatments are planned via computer algorithm there is a laborious process of plan checking and approval by staff before the dose can be delivered. Many plans are rejected and must be replanned, impacting on clinical efficiency. The research has determined that one algorithm metric - the ‘small aperture score’ [7] – can be used to accurately predict whether or not a treatment plan will pass Quality Assurance, allowing rejection of the plan without time consuming inspection. This research has fed into the development of machine learning frameworks for radiotherapy quality assurance and have increased clinical efficiency.

Two further examples of research outcomes with specific clinical impact, that are now in use in radiotherapy clinics in Australia and overseas, include improving treatments for breast cancer by optimising treatment planning algorithms to ensure they are accurate and that the beams treat the tumour without affecting nearby organs like the heart [8], and improving the accuracy of radiotherapy beams when patients have metallic implants such as hip replacements or breast expander ports [9].

Associated research

(Briefly describe the research that led to the impact presented for the UoA. The research must meet the definition of research in Section 1.9 of the EI 2018 Submission Guidelines. The description should include details of:
- what was researched
- when the research occurred
- who conducted the research and what is the association with the institution)

Small field radiotherapy: Radiation beams used in radiotherapy have generally been well characterised over a century of use, however, only as long as they are wider than about 1.5 cm. Below this size, their characteristics change and measurements become problematic, thus a lower limit to beam sizes of 3 cm was in practice for many decades, which prevented optimal treatments for cancer patients. The associated research, carried out by the QUT Radiotherapy Research Group in collaboration with clinicians between 2002-2016, investigated the underlying fundamental physics of small fields, in particular lateral electron transport within the beam, and how the beam interacts within materials and detectors.

Radiotherapy measurement and optimisation: As radiotherapy beams become more complex due to advances in technology, numerous issues arise with new techniques. While beams can be produced that move in the same way as a patient breathes and thus the accuracy of treatments can be greatly improved, this opens up new challenges such as actually tracking the motion of a tumour to allow synchronisation with the beam. Similarly, with some new treatments the linear accelerator rotates around the patient during delivery, further complicating synchronisation challenges. This research has concentrated on several topics in advances of radiotherapy, such as 3D visualisation of the beam, linear accelerator consistency, and development of tools to ensure accuracy such as software and metrics.

FoR of associated research

(Up to three two-digit FoRs that best describe the associated research)

02 - Physical Sciences

References (up to 10 references, 350 characters per reference)

(This section should include a list of up to 10 of the most relevant research outputs associated with the impact)

[1] Charles, P.H., G. Cranmer-Sargison, D.I. Thwaites, S.B. Crowe, T. Kairn, R.T. Knight, J. Kenny, C.M. Langton and J.V. Trapp (2014) A practical and theoretical definition of very small field size for radiotherapy output factor measurements. Medical Physics, 41(4):041707, p.1-8. DOI:10.1118/1.4868461

[2] Charles, P.H., S.B. Crowe, T. Kairn, J. Kenny, J. Lehman, J. Lye, L. Dunn, B. Hill, R.T. Knight, C.M. Langton and J.V. Trapp (2012) The effect of very small air gaps on small field dosimetry. Physics in Medicine and Biology, 57(21), p.6947-6960. DOI:10.1088/0031-9155/57/21/6947

[3] Cranmer-Sargison, G., P.H. Charles, J.V. Trapp and D.I. Thwaites (2013) A methodological approach to reporting corrected small field relative outputs. Radiotherapy and Oncology, 109(3), p.350-355. DOI:10.1016/j.radonc.2013.10.002

[4] Morales, J.E., S.B. Crowe, R. Hill, N. Freeman and J.V. Trapp (2014) Dosimetry of cone-defined stereotactic radiosurgery fields with a commercial synthetic diamond detector. Medical Physics, 41(11):111702, p.1-6. DOI:10.1118/1.4895827

[5] Morales, J.E., R. Hill, S.B. Crowe, T. Kairn and J.V. Trapp (2014) A comparison of surface doses for very small field size x-ray beams: Monte Carlo calculations and radiochromic film measurements. Australasian Physical & Engineering Sciences in Medicine, 37(2), p.303-309. DOI:10.1007/s13246-014-0260-2

[6] Kairn, T., A. Asena, P.H. Charles, B. Hill, C.M. Langton, N. Middlebrook, R. Moylan and J.V. Trapp (2015) Field size consistency of nominally matched linacs. Australasian Physical & Engineering Sciences in Medicine, 38(2), p.289-297. DOI:10.1007/s13246-015-0349-2

[7] Crowe, S.B., T. Kairn, J. Kenny, R.T. Knight, B. Hill, C.M. Langton and J.V. Trapp (2014) Treatment plan complexity metrics for predicting IMRT pre-treatment quality assurance results. Australasian Physical & Engineering Sciences in Medicine, 37(3), p.475-482. DOI:10.1007/s13246-014-0274-9

[8] Kairn, T., S.B. Crowe, C.M. Langton and J.V. Trapp (2016) Bulk evaluation and comparison of radiotherapy treatment plans for breast cancer. Australasian Physical & Engineering Sciences in Medicine, 39(3), p.633-644. DOI:10.1007/s13246-016-0454-x

[9] Asena, A., T. Kairn, S.B. Crowe and J.V. Trapp (2015) Establishing the impact of temporary tissue expanders on electron and photon beam dose distributions. Physica Medica: European Journal of Medical Physics, 31(3), p.281-285. DOI:10.1016/j.ejmp.2015.01.015

[10] Kairn, T., J. Kenny, S.B. Crowe, A.L. Fielding, R.D. Franich, P.N. Johnston, R.T. Knight, C.M. Langton, D. Schlect and J.V. Trapp (2010) Modelling a complex micro-multileaf collimator using the standard BEAMnrc distribution. Medical Physics, 37(4), p.1761-1767. DOI:10.1118/1.3355873

Additional impact indicator information

Additional impact indicator information

(Provide information about any indicators not captured above that are relevant to the impact study, for example return on investment, jobs created, improvements in quality of life years (QALYs). Additional indicators should be quantitative in nature and include:
- name of indicator (100 characters)
- data for indicator (200 characters)
- brief description of indicator and how it is calculated (300 characters).)