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INVITED COMMENTARY

Future forum, Hobart, October 29, 2017: examining the role of medical physics in cancer research

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Abstract

This commentary reports on a forum held in October 2017 in Hobart, Tasmania, attended by 20 Australasian medical physicists, to consider the future role of medical physics, as well as non-medical physics and allied disciplines, in oncology research. Attendees identified important areas of oncology research which physicists can be contributing to, with these evaluated in the context of a set of "Provocative Questions" recently generated by the American Association of Physicists in Medicine. Primary perceived barriers to participation in research were identified, including a "lack of knowledge of cancer science", together with potential solutions. Mechanisms were considered for engagement with the broader scientific community, consumers, advocates and policy makers. In considering future opportunities in oncology research for medical physicists, it was noted that a professional need to focus on the safety and accuracy of current treatments applied to patients, encouraging risk-aversion, is somewhat in competition with the role of physical scientists in the exploration and discovery of new concepts and understandings.

Keywords Oncology · Cancer · Medical physics · Research · Future

Background

Medical physicists have contributed substantially to the development of methods for the diagnosis and treatment of cancer, and applications of ionising radiation represent perhaps our finest achievements. In radiation oncology for example, such contributions have primarily focused on precisely and accurately delivering a high radiation dose to the tumour while keeping normal tissue dose to a minimum, a goal which has spawned an entire industry employing the majority of medical physicists. Unlike the burgeoning field of cancer imaging, our contribution to therapy now sees many of us in research seeking incremental improvements in targeting radiation and increasing the probability of tumour control without significant toxicity. It has seen those of us in the clinic ensure that our relevant expertise is used to define a professional role, well demarcated with carefully-constructed certification programs, and intimately linked to a select cohort of equipment manufacturers.

On the other hand, cancer biologists have generated an entirely new understanding of carcinogenesis and the tumour environment over the last couple of decades [1]. Biophysics and allied disciplines have made enormous inroads into understanding the fundamental processes associated with tumour formation and progression [2, 3]. However there is little motivation for device-based oncology to evolve from the status quo and to undertake research to adapt these new understandings to clinical interventions. The unfortunate consequence is likely to be a narrowed relevance of the medical physics profession in oncology. The ramifications for the profession were identified by the American Association of Physicists in Medicine (AAPM) who launched initiatives to address this including the Working Group on Future Research

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and Academic Medical Physics (FUTURE). Amongst the actions of the FUTURE Working Group is a range of "expanding horizons" initiatives, one of which involves defining 'Provocative Questions'—questions which may be addressed by physical and allied scientists and which, if answered, would enable significant progress in oncology [4]. This mimics the efforts of the National Cancer Institute of the United States to provoke researchers to address important key topics [5].

To instigate similar efforts in the Australian and New Zealand setting, a "Future Medical Physics—Rethinking Cancer" day-long forum was held prior to the 2017 Engineering and Physical Sciences in Medicine (EPSM) conference in Hobart. This report comprises a summary of the forum and its outcomes, compiled from presentations and notes from the day, and reviewed by all participants listed in Appendix 1.

Forum

Twenty attendees from diverse regions and with an academic focus or specific cancer research experience (see Appendix 1) considered how medical physicists in Australia and New Zealand can diversify their cancer research efforts. In this Australia/New Zealand context, the forum considered multiple questions regarding:

- the current nature of oncology research being undertaken by medical physicists;
- the capacity to expand that research and to focus on applications of physics to the fundamental nature of cancer;
- barriers for physicists to engage in oncology research;
- groups to collaborate with to improve oncology research outcomes;
- the implications for clinical medical physics in Australia and New Zealand, and;
- the implications for the education and training of medical physicists.

As a guide for this process, the forum considered the AAPM's efforts to expand research horizons using a Provocative Questions approach. Similar efforts are being also considered elsewhere internationally. The ultimate goal of all these efforts is to prepare a long-term "roadmap" for medical physics research at the highest level, synergize initiatives globally to tackle "big questions" and ultimately secure the academic and clinical relevance of medical physics for the foreseeable future.

Survey of important areas

An initial survey was taken to determine, for each attendee, the three most important areas of oncology research that physicists can be contributing to. Table 1 summarises the areas of importance in cancer research identified by the forum attendees, crudely clustered into themes. A word cloud for the identified areas is shown in Fig. 1a, highlighting the themes of treatment, imaging and data, as well as tumour metastasis which, relative to its recognised importance, is a relatively poorly studied area, particularly in medical physics [6]. The areas identified in Table 1 should be compared with the with the service-defined (and hence very narrowly-focused) areas of interest recently identified by clinical radiation oncology medical physicists [7].

In the subsequent discussion, a number of points were raised. Despite notably missing from the forum survey responses, discussion highlighted that physicists need to be sensitive to the needs that are identified in the clinical setting. A greater focus on patients has recently been identified as a crucial area of clinical service provision for medical physicists [8], and greater physicist presence in multidisciplinary meetings was suggested. Also absent from survey responses was reduction in treatment toxicities, but subsequently the forum recognised a role for physicists contributing to research into the patient pathway, quality of life assessment and survivorship. Lastly, computational biology is a rapidly expanding field. Physicists have unique skillsets in problem solving via computational models; this skillset should be applied in the biology space.

Commercialisation/income was identified as a key driver for priorities; however an overall mediocre track record in research commercialisation by Australasian medical physicists was highlighted. The areas identified in the survey did not relate to equipment manufacturers and relate minimally to specific techniques. The point was also made that an alternative driver can be the value-adding that research achieves. Medical physicists have the capacity to work outside of process driven workflows and research and development are seen as unique components of the vocation that should be embraced.

The AAPM's provocative questions in oncology research

The AAPM identified provocative questions in cancer by surveying members and associates and through workshops with biophysicists, cancer biologists and oncologists [4], extending beyond the background and experience of most

Table 1 Summary of important areas of cancer research where physicists can contribute as identified by attendees, clustered by general area (multiple identical responses in bold)

Nature of cancer
– **Metastasis**, physics of metastasis, progression
– Tumorogenesis
– Differences in physical characteristics of cancer/normal cells
Biology
– **Computational biology**
– Radiation biology
Treatment
– **Radiotherapy treatment**, planning, delivery, accuracy, automation
– **Immune response**
– Treatment options
– Targeted therapies, targeted drug delivery
– Radiation dosimetry, novel dosimetry
Personalisation
– Genomics
– Radiomics
– Treatment based on personal response
– Adapting to cancer evolution during treatment
Data analytics
– **Epidemiology**
– **Artificial intelligence**
– Learning from data/**bioinformatics**
– Big data
– Automated clinical data collection
– Analysis of clinical data
Diagnosis/imaging
– Diagnostics, tumour detection
– Imaging
– Molecular imaging, quantitative imaging, image analytics
– Use of MR in radiotherapy treatment planning
– Imaging of radiation damage
– Measurement/analysis of complex signals to characterise tissues/processes
Miscellaneous
– Applications of new materials
– Health economics as applied to developing countries
– Project management

forum attendees. The current AAPM provocative questions (listed in Appendix 2 and summarised by word cloud in Fig. 1b) were reviewed and discussed, with the following observations.

It was agreed that the provocative questions approach could be an effective way of instigating change in research culture and informing more effective directions. The questions are currently in a very esoteric language and will require considerable interpretation for non-specialists. We should identify which questions could best be addressed in the Australasian setting, matched to local expertise and infrastructure. That effort would also synergize with global efforts, particularly through the recently established topical group on medical physics (GMED) within the American Physical Society (https://www.aps.org/units/gmed/). The questions do not just provide guidance, but also mechanisms to gain support for current or future research from advocacy groups and funding agencies. It was noted how frequently 'model' is mentioned in the questions, identifying modelling as a central role for physicists. There are no questions targeting the evolutionary origins of cancer and/or its link to life origins, speciation and future challenges such as space travel, all of which are well within the realm of physicists/mathematicians. Despite large disparities in access to cancer treatment, resolution of which would have large public health

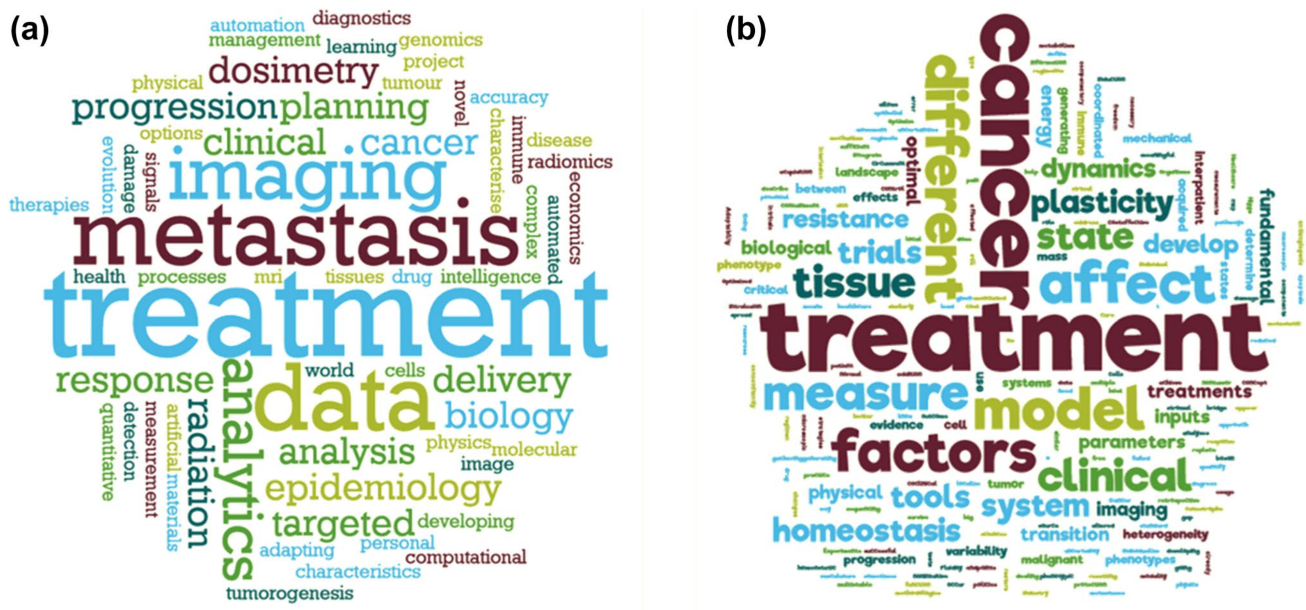

Fig. 1 Word clouds formed from **a** the survey-identified areas of cancer research which medical physicists can be contributing to, and **b** the current AAPM provocative questions

benefit, there are no questions targeting more equitable global access to cancer diagnostics/therapy. The questions do not link topics to equipment manufacturers and commercial interests, despite a prevalence of such interests in guiding current research being undertaken in the clinic.

There was discussion on some of the AAPM's 2017 specific questions (see Appendix 2), with the following comments:

- Question 8 (how to model multi-stable systems): This was seen as a very appealing question, well suited to physicists and having broad implications.
- Question 15 (uncertainty in clinical measurements): This could be seen as a key question for Australasia given current strengths in pre-clinical and clinical imaging and current efforts to link imaging to the clinic via modelling.
- Question 17 (replacing clinical trials): Current difficulties in encouraging large-scale collection of outcomes data for patients not participating in trials were highlighted. This is certainly something practising medical physicists can help to address. Innovative ways to assess patient outcomes that improve the efficiency of trials processes are being keenly sought (see for e.g. [9]).
- Question 18 (cost-effectiveness for individual patients): This was seen as a general, multi-faceted question towards which many (if not all) current research projects could be directed (i.e. it does not necessarily encourage new thinking).

Several attendees at the Hobart forum highlighted the need to repeat the process of generating provocative questions across other areas of medicine (e.g., neurosciences, cardiology, infectious diseases), potentially areas physicists do not have a traditional foothold in. This included the likely ability of physicists to contribute to health economics/logistics research, such as by using modelling to address the very practical problems of bed-blocking/ambulance-ramping in hospitals.

It was also suggested by forum attendees that the AAPM's provocative questions be used to lobby and stimulate direction from national science groups and funding agencies. This would include national health and scientific research support agencies, national cancer research agencies and national academies of science (the latter seen as an avenue to national political forums). The questions are not cancer-site specific, a potential disadvantage for funding applications since sources are usually siloed. Conversely, the questions can be interpreted in many site-specific contexts and have significant flexibility in interpretation in order to match patient/social priorities, priorities of advocacy groups/funding agencies, availability of data/tissue etc.

Barriers to medical physics oncology research

An initial survey was taken to determine, for each attendee, the three most significant barriers to medical physicists contributing to research in oncology. The forum narrowed these down to five main issues, listed below together with associated discussion points which include some ways to overcome the barriers.

(Clinical) medical physicists are not paid to do research

Clinical medical physics is a relatively well rewarded profession. Conducting research is one means by which value can be demonstrated; moreover automation is taking over some routine work and freeing up time for research. The benefits of research in the clinical setting may be unclear and need to be demonstrated to administrators. In many job descriptions the role for research is often poorly defined and interpreted to suit individual agendas. Where expected, the pressure to undertake research in a clinical setting can be highly stressful. It was also noted that there is likely a generational difference in the attitude of clinical physicists to research (many problems where a solution had to be 'researched' are now solved via manufacturer-provided solutions). To overcome this barrier, incentives for 'clinical' physicists to undertake research can be provided via incentives in salary/conditions, provision of time, and encouragement from management, but an inherent motivation in the individual is also required.

Funding and resources are not available

Full-time researchers are frequently employed from grant-to-grant; this lack of certainty results in attrition of full time researchers. Despite a willingness and motivation to perform research, clinical staff lack time, support and expertise to apply for funding. To increase funding and resources, medical physicists should be nominating for representation on grant review panels to gain expertise in grant writing and tactics, as well as promote the role and expertise of medical physicists in the health science community. Workshops can be held focusing on research project definition, publication, protocol writing, grant writing and track-record development. Relative to other global regions we have a small and cohesive community and thus considerable scope for cross-institution collaboration, providing stronger funding applications. There is a need to maintain a consistent message across multiple levels of advocacy/funding agencies. The ACPSEM could consider seed-funding options (as provided by RANZCR, AIR) and/or calls from philanthropy.

Physicists have a lack of knowledge of cancer science

As highlighted in the understanding of the provocative questions, we need to be able to speak the language of other cancer scientists. However, by being experts in our own space, we have something to bring to a multi-disciplinary table. We risk isolation if we do not demonstrate our worth outside of our current narrow application.

A number of suggestions to overcome this barrier were suggested. Medical physicists would benefit from attending more diverse conferences outside of traditional medical physics, radiation oncology and medical imaging fields (e.g. the Lorne cancer conference). Medical physics attendance and participation in multidisciplinary meetings should increase and those who have done it report typically that they were well received. MSc/TEAP material could be reviewed for generality/diversity, potentially with input from clinicians. Continuous professional development (CPD) must provide avenues for knowledge expansion both within and outside of traditional medical physics. These suggestions may provide pathways to successful collaboration outside of our profession which will further diversify our knowledge base.

Physicists are not visible in the cancer research landscape

A common lack of awareness of the medical physics profession outside of radiation oncology and medical imaging was highlighted. We need to seek recognition from other professions in the cancer research community. Initial steps to surmount this barrier again start with involvement in multi-disciplinary teams. There is the potential to achieve specialist knowledge in specific tumour streams as well as to showcase the value of medical physics expertise. There are also opportunities to give presentations/in-services in our institutions as well as at other conferences (e.g. IEEE, AIP, COSA). Key skill sets which have great utility across all cancer research (e.g. statistics, data modelling) can be fostered and promoted to other research groups. The ACPSEM can support promotion of medical physics through developing forums on inter-discipline collaboration (e.g., with other professional societies), as well as a presence for research on the ACPSEM website and via social media. Greater interaction with patient/advocacy groups (e.g. cancer voices) would also be beneficial.

It was highlighted that internationally, the important role for physicists in oncology research is becoming increasingly recognised. This is evident, for example, by the establishment of journals focused on the convergence of physical and allied sciences on oncology (such as "Convergent Science Physical Oncology" [10] and "Cancer Convergence" [11]) and the efforts by the United States National Cancer Institute to establish a network of centres focused on physical sciences in oncology [12].

We don't have the right people

The current workforce is not trained appropriately; research requires a critical mass of suitably trained and motivated scientists and many clinical physicists are not part of such a mass. Medical physics recruitment needs to expand outside the current clinical space; there is also a need for people with different skillsets, and/or the capacity to embrace the entry of people with diverse skillsets into the medical physics profession. Compared with other 'service providing' occupations, medical physicists have a large amount of flexibility in their time allocation—this flexibility should be embraced and exploited. Moreover more capability in engagement with executive and at government levels is required.

It is suggested workshops be held to develop the knowledge and skills of current practitioners. Collaboration can be encouraged with larger departments, or across regions by forming regional collaboratives. Through active engagement with colleagues with similar interests and other healthcare professionals, a research culture across the profession is achievable.

Engagement with community, stakeholders and collaborators

A led discussion focussed on aspects of engagement with other disciplines, stakeholders and agencies, how such engagement can assist medical physicists to advance oncology research and overcome the identified barriers. The following points summarise the discussion.

General engagement principles

In any engagement process the benefits for the stakeholders need to be made very clear. Engagement of research-capable medical physicists should happen early in their academic careers. Social media is a powerful medium for canvassing support and promoting medical physics, and a number of examples were provided. Equipment manufacturers have become established collaborators and will likely remain so.

Consumer and advocacy engagement

Patients, consumers and advocacy groups can be considered collaborators. Engagement with 'consumers' can be considered very rewarding and beneficial for researchers. Engagement at project inception is important, and mandatory for many funding agencies. Consumers are the most powerful medium for lobbying government.

Professional organisations (i.e. the ACPSEM) could provide a formal conduit to enlisting philanthropic support (e.g. from companies and donors).

Multi-disciplinary engagement

Currently the medical physics community is relatively homogenous. Diversification through specialisation and multi-disciplinary collaboration is a mechanism to create a more robust and effective research capability. Identifying our own strengths and what we can bring to the table can facilitate engagement with other professions such as non-medical physicists and allied disciplines (mathematicians, engineers, computer scientists). This could be achieved via institutional, regional and national inter-disciplinary meetings and by presenting such disciplines with problems in cancer research where their expertise and skills could be used to find solutions (such as by casting the provocative questions into appropriate discipline-specific language). The focus of the provocative questions is the traditional domain of biologists. The onus is on us to learn the language of biology to engage them.

Engagement with decision makers

Medical physicists can and should engage with government via multiple avenues such as representation on national grant review panels and agencies, science advocacy groups (e.g. National Academy of Science, Science and Technology Australia) and government-sponsored mechanisms (e.g. Eureka Awards, Science Meets Parliament).

Future role of medical physicists in oncology research

A published editorial from Bortfeld et al. [13] well illustrates the challenges of reconciling the need for medical physicists to maintain a focus on the safety and accuracy of current treatments applied to patients, encouraging risk-aversion, with the role of physical scientists in the exploration and discovery of new concepts and understandings. With this in mind, the forum undertook a SWOT (strengths, weaknesses, opportunities, threats) analysis of the capacity of medical physicists to have an increased role in cancer research, as summarised in Table 2.

A survey was taken of attendees, giving responses to a series of statements focusing on medical physicists

Table 2 SWOT analysis of the future role of medical physicists in cancer research

Strengths	• Expertise that is relatively unique and well demarcated
	• Expertise, experience and a tradition of translational research
	• A relatively small and close-knit community with exceptional capacity for collaboration
Weaknesses	• Relatively poor skills in communication and promotion
	• Limited/incomplete range of knowledge and skills
Opportunities	• Access to data and skills to generate outcomes evidence
	• Opportunities to broaden applications of physics and engineering
	• A clinical presence
	• A clear certification process and an associated code of ethics
	• Research as a revenue-generating opportunity
	• Geographic location (most populated region and time zones)—opportunities for education, training, collaboration, development of emergency response
Threats	• Automation (vendor-driven), impacting the size of the medical physics workforce
	• Inadequate breadth of training
	• Being seen as (or becoming) recipe-following technicians
	• Being too narrowly focused on cancer
	• Difficulty in demonstrating skills value
	• Lack of (research) management skills
	• Limited academic recognition and presence (small student numbers)

undertaking oncology research in Australia and New Zealand. These responses are summarised in Appendix 3, with a number of specific outcomes worth highlighting. There was *general agreement* that medical physicists in Australia and New Zealand can be undertaking more and more novel oncology research. There was *strong agreement* that Australia and New Zealand are appropriate places for physicists to undertake oncology research. There was *strong disagreement* that there should be a clear separation between academic/research and clinical physics. These points are balanced however with the majority of attendees disagreeing that medical physicists received appropriate training, including in undergraduate programs, to undertake oncology research.

In response to the statement, "If I managed an *academic* department, I would prefer to employ someone who has passed their TEAP examination over someone with relevant overseas postdoc experience", most attendees disagreed. However, in the context of a *clinical* department, there was division of opinion.

It should be noted that given the specific selection of forum attendees there is considerable chance for responses that do not necessarily reflect those of medical physicists in general.

Future

The forum focussed specifically on the contributions of medical physicists to research in oncology, mainly as a convenient starting point given current expertise, the likelihood of buy-in by colleagues and because of the challenge to change the direction of a field with considerable existing momentum. The forum included minimal distinction between clinical medical physicists and those working in academia or other industries, though such distinction will likely be necessary. A succinct case for physicists in general to contribute to cancer research, a field which consumes enormous resources and which seemingly makes very slow progress, was recently made by Austin [14]. However, the general associated concepts apply in most areas of medicine.

This forum represents one small step in a process of re-evaluating the priorities for research in oncology, encouraging an examination of cancer from its basic physical principles. It is hoped that medical physicists will pay a keen interest in that process, adapting their profession, knowledge and capacity to translate such new fundamental understandings to effective clinical interventions. As identified, this cannot be achieved in isolation and requires substantial collaboration across disciplines. It also requires a global paradigm shift, and it is noted that the discussion at this forum was well aligned with that reported from a similar 2014 forum organised between the AAPM and the European Federation of Medical Physics (EFOMP). We will continue to work with international medical physics and allied groups to achieve a revolution in our approach to cancer research.

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Compliance with ethical standards

Conflict of interest All authors declare no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Appendices

Appendix 1: participants

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Stephanie Corde, Prince of Wales Hospital, New South Wales.
Jeff Crosbie, RMIT University, Victoria.
Scott Crowe, Royal Brisbane and Women's Hospital, Queensland.
Yves De Deene, Macquarie University, New South Wales.
Martin Ebert, Sir Charles Gairdner Hospital, Western Australia (forum facilitator).
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Lois Holloway, Liverpool Hospital, New South Wales.
Price Jackson, Peter MacCallum Cancer Centre, Victoria.
Tanya Kairn, Genesis Cancer Care, Queensland.
Tomas Kron, Peter MacCallum Cancer Centre.
Jayde Livingstone, Australian Synchrotron, Victoria.
Peter Metcalfe, University of Wollongong, New South Wales.
Natalka Suchowerska, Chris O'Brien Lifehouse, New South Wales.
Brendan Whelan, University of Sydney, New South Wales.
Ivan Williams, Australian Radiation Protection and Nuclear Safety Agency, Victoria.

Appendix 2: AAPM's 2017 provocative questions

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1. Can we develop physical models of "tissue homeostasis"—maintenance of a stable state?
2. What factors cause the disruption of "tissue homeostasis" that allow emergence of a cancer phenotype?
3. Is there a critical tumour mass that leads to progression to a malignant cancer phenotype?
4. How can we model cell population dynamics across the continuum of cell phenotypes?
5. Is aging a fundamental input to the cancer model?
6. How can we measure factors (e.g., physical, biological, mechanical) that affect cancer induction, local progression and metastatic spread, and inter-patient variability?
7. Why are the fundamental changes of tissue homeostatic state to malignant phenotype (e.g., metastases, acquired drug resistance, altered metabolism, resistance to apoptosis and immune protection) coordinated?
8. How can we model multi-stable systems that describe biological systems, such as immune system function?
9. How can we model cancer's different usage of resources (e.g., energy) which do not appear optimal, but which help cancer survive?
10. How can we model plasticity and measure the heterogeneity of epithelial cells and stromal components (intra-lesion, inter-lesion, inter-patient) and their dynamics?
11. How do we model cancer treatment and treatment effects?
12. What is the optimal treatment regimen (modality, dose, timing) to achieve different endpoints (containment of cancer, cancer cure, normal tissue damage)?
13. Can we measure treatment resistance (intrinsic, acquired, compensatory)?
14. Can we localize the source of pain (e.g., with imaging)?
15. How can we quantify and address uncertainty in all clinical measurements (e.g., imaging, other tests)?
16. How can we model the parameters to bridge the gap between microscopic and macroscopic sciences, different model organisms?
17. What can replace clinical trials as a means of generating evidence?
18. Can we determine the most cost-effective clinical pathways for any individual patient in a given healthcare system?

Appendix 3: outcome survey results

See Fig. 2.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
a) In general, medical physicists in Australia/NZ need to revise their approach to oncology research	7	7	3	0	0
b) Medical physicists in Australia/NZ can be making more substantial contributions to oncology research	8	9	1	0	0
c) Medical physicists in Australia/NZ have appropriate education/training to undertake broad oncology research	0	2	3	13	2
d) Clinical medical physicists should prioritise immediate incremental improvements in imaging and treatment rather than longer-term questions	0	4	8	6	2
e) Current undergraduate programs equip physicists appropriately for contributing to oncology research	0	2	5	9	3
f) Current postgraduate programs equip physicists appropriately for contributing to oncology research	0	7	9	2	3
g) Clinical physicists should focus more on treatment safety than new techniques	0	2	6	6	4
h) There are still substantial opportunities to improve cancer detection and treatment with current technologies/techniques	12	4	2	0	2
i) If I managed a clinical department, I would prefer to employ someone who has passed their TEAP examination over someone with relevant overseas postdoc research experience	1	4	9	3	2
j) If I managed an academic department, I would prefer to employ someone who has passed their TEAP examination over someone with relevant overseas postdoc experience	2	0	2	9	5
k) Australia and New Zealand are appropriate places for physicists to undertake research in oncology	8	9	0	1	0
l) Funding for oncology research is relatively readily available for physicists	0	2	2	9	4
m) There should be a clear separation of academic/research physics and clinical physics	0	0	2	10	5
n) Oncology research by clinical physicists is largely tied to equipment manufacturers	1	6	6	4	3
o) There is scope within the current ACPSEM TEAP system for novel oncology research	2	3	2	6	6
p) This forum has been useful for me personally to consider the role of physicists in oncology research	14	5	0	0	0
q) This forum will be useful in general for improving efforts of physicists to contribute to oncology research	10	8	1	0	0

Fig. 2 Summary of responses to survey questions. Numbers indicate frequency of response out of 19 complete surveys

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