Imaging research in the UK: An NCRI survey

NCRI
National
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Executive summary

Background

During the course of the National Cancer Research Institute (NCRI) Positron Emission Tomography (PET) Research Initiative (www.ncri-pet.org.uk), the question was raised about how coordination efforts in PET do, and should, relate to coordination in cancer imaging more broadly. Imaging research involves many scientific and medical disciplines, and with so many modalities, techniques and possible intervention points in a patient's cancer journey, it is difficult to get an overall picture of where the needs and opportunities lie.

The NCRI conducted a survey of the research community in 2012 to gather opinion on cross-modality needs in imaging coordination, cascaded by email to NCRI contacts and lists of cancer and imaging experts. This information will be used to explore which areas may need further collaborative support to succeed.

Respondents

In total, 157 people responded to the questionnaire, with a good mix of disciplines and modalities represented. Most respondents worked in cancer imaging, though there were also representatives with experience beyond cancer. There was a fairly even split between respondents working in academia and the NHS, with a small representation from industry. Respondents reported using imaging in a variety of ways in their research – most commonly in a clinical trial setting, but a number of representatives had expertise in developing imaging technology, quality assurance, preclinical imaging, population-based screening and capacity development.

Strengths

The presence of skilled researchers was the most frequently mentioned strength, followed by the investments that have been made in high quality imaging equipment. There was enthusiasm for the NHS as a delivery vehicle for clinical imaging research, particularly when coupled with the complementary infrastructure of trials networks and clinical trials units. Respondents saw the possibility to recruit large numbers of patients into trials, with the UK benefiting from structured referral routes, a strong clinical trials culture, and patients proving willing to engage with research. A number of people commented on the data linkage opportunities that come from having centralised clinical systems, and the strength of basic science in the UK.

Weaknesses

Funding was the topic most commonly mentioned as an area of weakness, not so much due to an absence of opportunity to apply, but rather from the high overall cost of this kind of research, and the challenges of meeting these costs at a local level in the NHS. Specific shortcomings included gaps in funding for underpinning or research-enabling work, and difficulty securing funding for translation of basic research into clinical application. It was also felt that the high costs of imaging trials had led to smaller studies, sometimes underpowered, being more successful at achieving funding than more ambitious applications.

Fragmentation came up as a weakness, in a number of contexts. Examples included competition for funding between groups preventing collaboration, a lack of communication between disciplines and between researchers working on different imaging modalities, and a lack of centralisation of processes and protocols. A number of respondents mentioned the imbalance of resource between centres as a weakness; the few centres with high-level funding, and the many without.

Lack of research capacity was a dominant theme, and respondents from radiology, physics, radiography and nuclear medicine all expressed views that there were ways for members of their discipline to contribute more fully to research if time pressures could be lifted and training opportunities increased.

Opportunities

Although expressed in a variety of ways, there were really two main themes in opportunities: Encouraging research groups to collaborate with each other on topics of shared interest; and tapping in to the infrastructure we have in place for clinical imaging, data transfer and clinical trials in cancer.

People were in favour of creating structures that allowed imaging researchers to work together more closely, and finding ways that collaborative efforts could be incentivised. These comments were generally from the clinical arena, as basic science and technology was seen as needing space for innovation and ownership of ideas. There were a number of calls to avoid duplication of effort by centralising core activities such as QA, radiopharmacy, and training opportunities. Having standardised protocols and common software tools for acquisition and analysis was considered important to enable multicentre work delivered through the NHS.

Many wanted to tap into the strong clinical trials culture in the UK for exploring new imaging methods, with the potential to make greater research use of the advanced technology that is already in place for imaging. Respondents also saw the potential of PACS (the NHS Picture Archiving and Communications System), as the images gathered could form a huge resource that, with the appropriate management and governance, could be very valuable for research purposes.

Barriers

The barriers overlapped significantly with responses given under 'weaknesses'. Funding for research was again the most prominent issue, including the high overall costs of imaging, difficulty competing against 'cheaper' studies, and gaps between funding streams. Process issues featured heavily, both in terms of slow and labour-intensive regulatory procedures, and difficulties in the relationship with R&D departments and covering the NHS costs of imaging research.

In the clinical setting, lack of time for research and access to equipment for research purposes were also key barriers. Several mentioned the need for out of hours research, and some noted that the pace of technology development means service development takes priority over research.

Respondents also expressed difficulties working across disciplines, and a lack of research culture, predominantly within radiology. This was seen as being in parallel to or as a result of inadequate research training and experience, a lack of institutional support for participation in research, and a lack of academic recognition for radiologists.

Research priorities

This was a very open question about what the priorities should be for imaging research, and as expected there were a wide variety of responses. The most frequently cited priorities were about development and validation of imaging biomarkers (for assessment of disease status and assessment of treatment response), and standardisation of techniques for their determination.

A number of respondents expressed a desire for greater use of quantitation in imaging, and a need to standardise protocols and analysis tools in order to provide the kind of rigor that makes research clinically useful. Several mentioned opportunities for correlation of imaging data with pathology markers. PET and MR were the most commonly mentioned individual modalities, with plenty of support for multimodality imaging. Some spoke of ambitions to refine the current technologies, such as increasing sensitivity, focusing on non-ionising imaging, and improving motion correction.

Ways to increase impact

Collaboration was the most prominent theme. Some expressed this as a need for national coordination, others favoured a less rigid approach to reduce competitiveness between centres and incentivise closer working, for example funding calls that mandate multicentre working. Competition for funding was acknowledged as being necessary to keep standards high, but also felt to be divisive in its present form. Respondents wanted to see the leading imaging centres taking a greater role in skill sharing, and in helping to break down barriers between centres.

In terms of working more closely across disciplines, there were two main angles. The first was that radiographers and radiologists appear to feel undervalued within research teams, and their engagement with research is limited. The second is about closer working between clinicians and scientists, to bridge the gap in translating innovations into clinical use. Some felt the clinical relevance of developments could be increased by broader, earlier collaboration between academic and clinical teams. Suggestions for improving on the ground support for research included greater use of technicians within radiology departments, and greater involvement of statisticians.

Making better use of data was again prominent, with many feeling that with the right standardisation and QA in place, research data should be more widely shared and used for research purposes. Respondents also talked about ways to drive up the quality and impact of research that is being done now, by developing common protocols, harmonising methods, providing capacity for central review, and setting standards for data gathering. Several saw the potential to 'go the extra mile' with current trials to get more value out of a single piece of research, whether by adding an imaging question to cancer trials or capturing pathology data in parallel to imaging work.

Areas in need of coordination

Many respondents had proactively identified coordination as a priority at earlier stages in the survey, so there was a degree of overlap with previous responses. Finding ways to encourage multicentre working was the biggest request, but a feeling that this may need to be incentivised or facilitated to be effective.

Asking this explicit question about coordination drew out a range of practical suggestions. These included a strong message about developing standards and common practices, and avoiding duplication of effort by providing central sources of information such as details of ongoing imaging trials, methods and protocols. Others advocated coordinating the provision of advice, support and training, and ensuring that imaging representation is built into other groups.

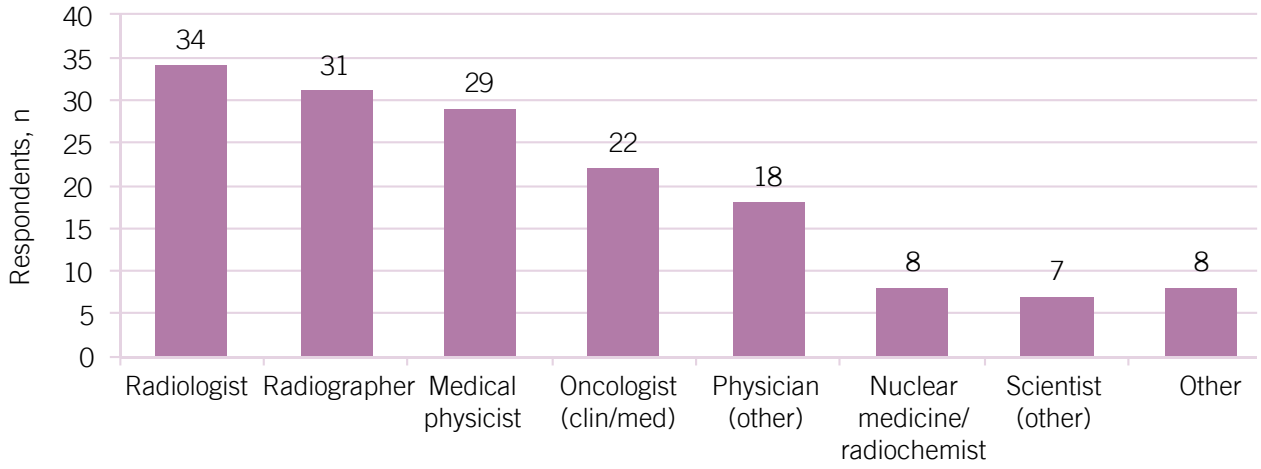
1. Introduction

The NCRI released a survey on imaging research in 2012 to capture opinions from the UK community about the strengths, weaknesses, opportunities and barriers to imaging research, the areas where greater coordination may be beneficial, and the types of advances that were felt would make the greatest impact on cancer in the next decade.

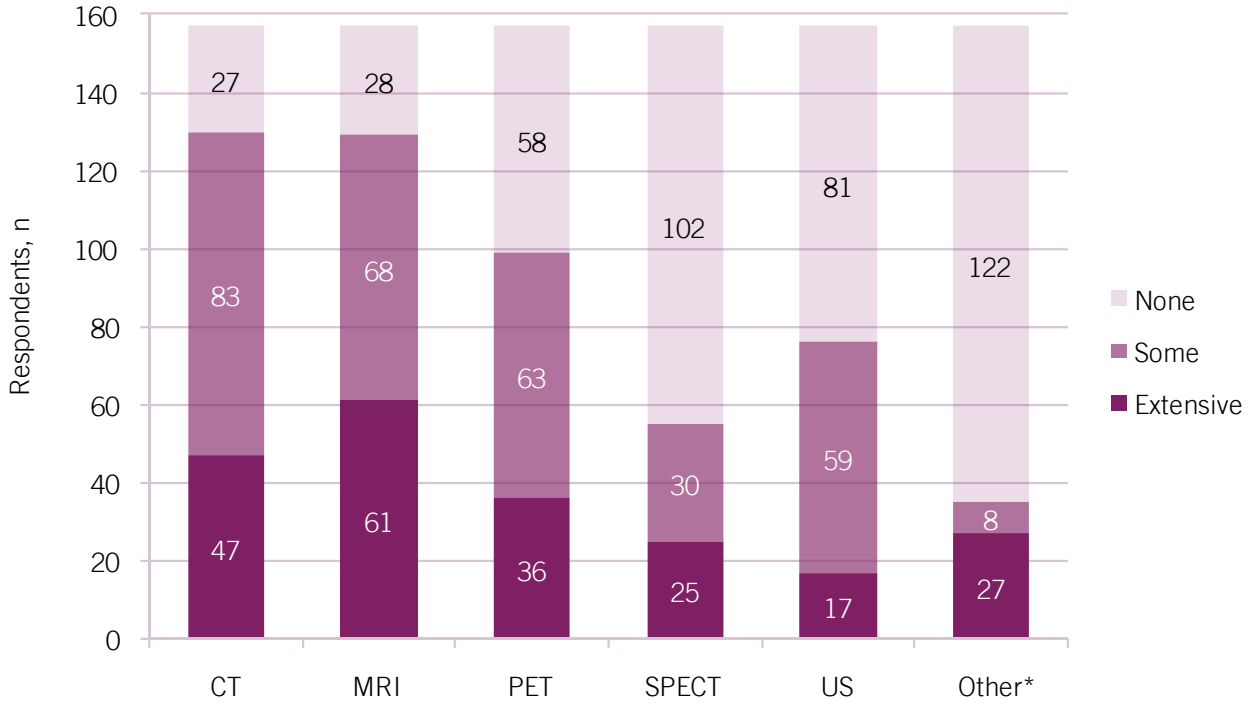
The survey was designed by the NCRI Secretariat and issued online in SurveyMonkey, with data collection open between 7 February 2012 and 15 March 2012. The survey link was cascaded via email lists and made available on the NCRI homepage and via the NCRI newsletter.

In total, 157 people submitted responses to the questionnaire. Not all questions were mandatory, and some questions allowed more than one response to be selected per person, so denominators are shown for the results on a per-question basis.

Disciplines (N=157; one answer per respondent)

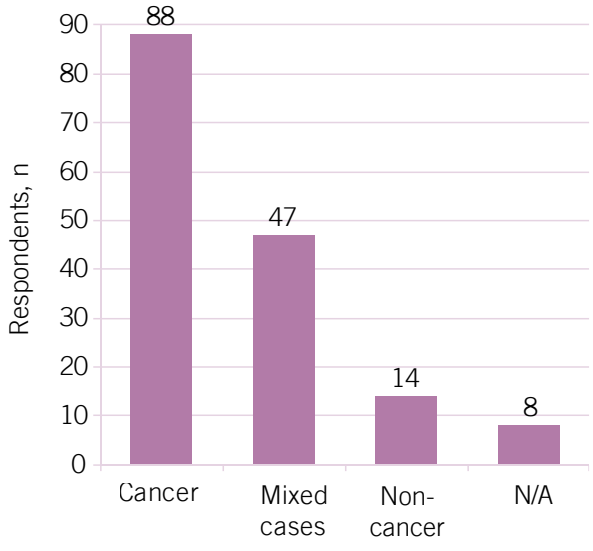


Modality expertise (N=157; one answer per category)

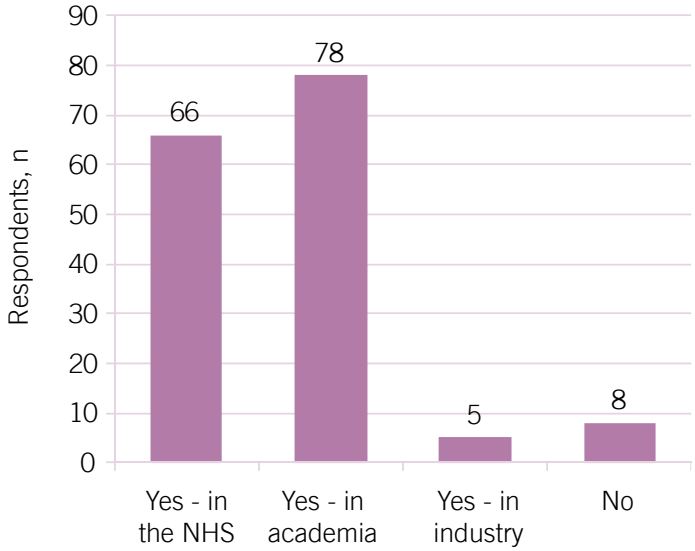


*Modalities cited in the 'other' category include plain film x-ray, fluoroscopy, magnetic resonance spectroscopy, optical spectroscopy, mammography, cone beam CT, magnetoencephalography, high intensity focused ultrasound, bone densitometry, DEXA, angiography, image-guided radiotherapy, MV/kV online imaging in radiotherapy, clinical confocal microscopy, optical coherence tomography, and digital dermoscopy.

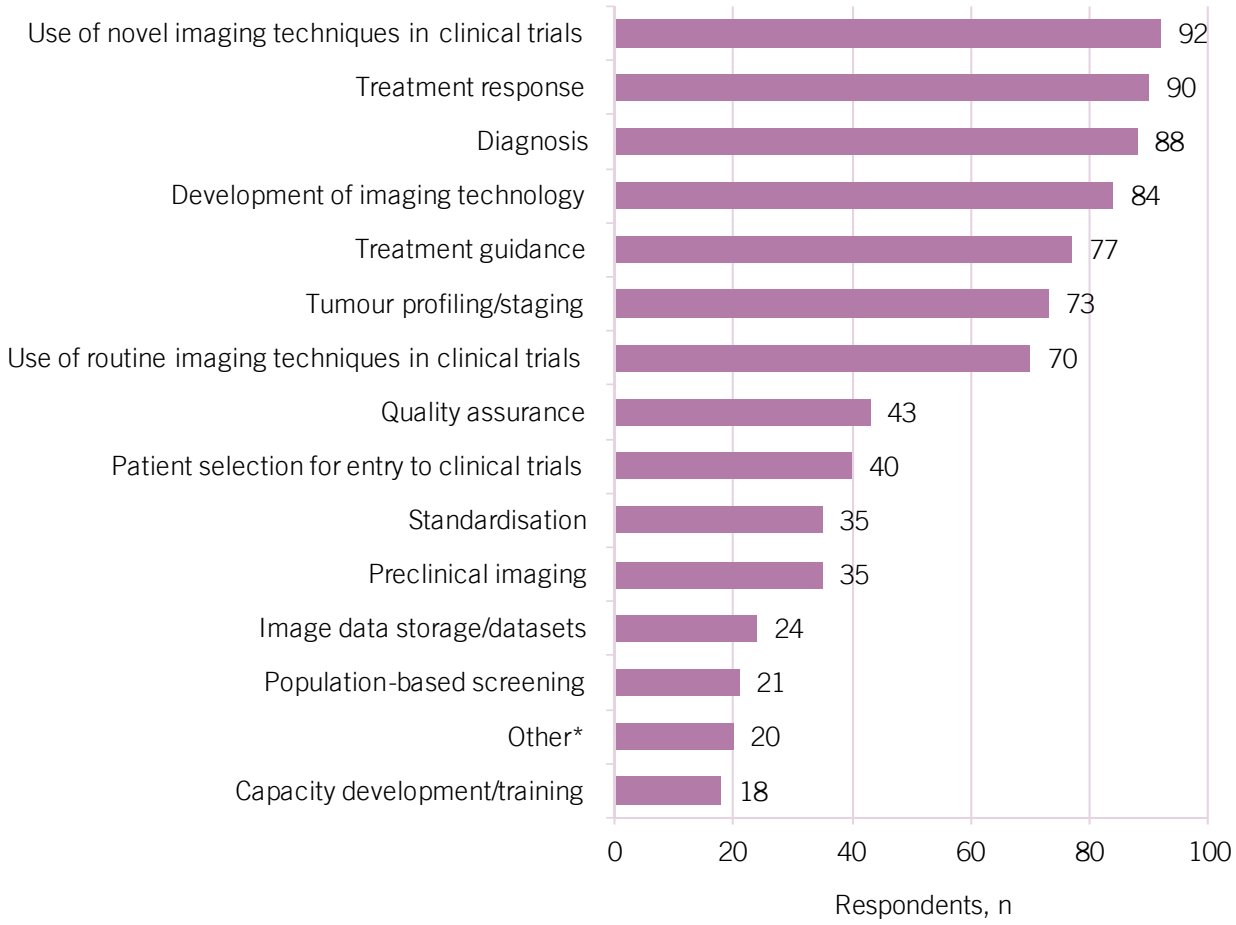
Disease focus of imaging work (N=157; one answer per respondent)



Involvement in imaging research (N=157; one answer per respondent)



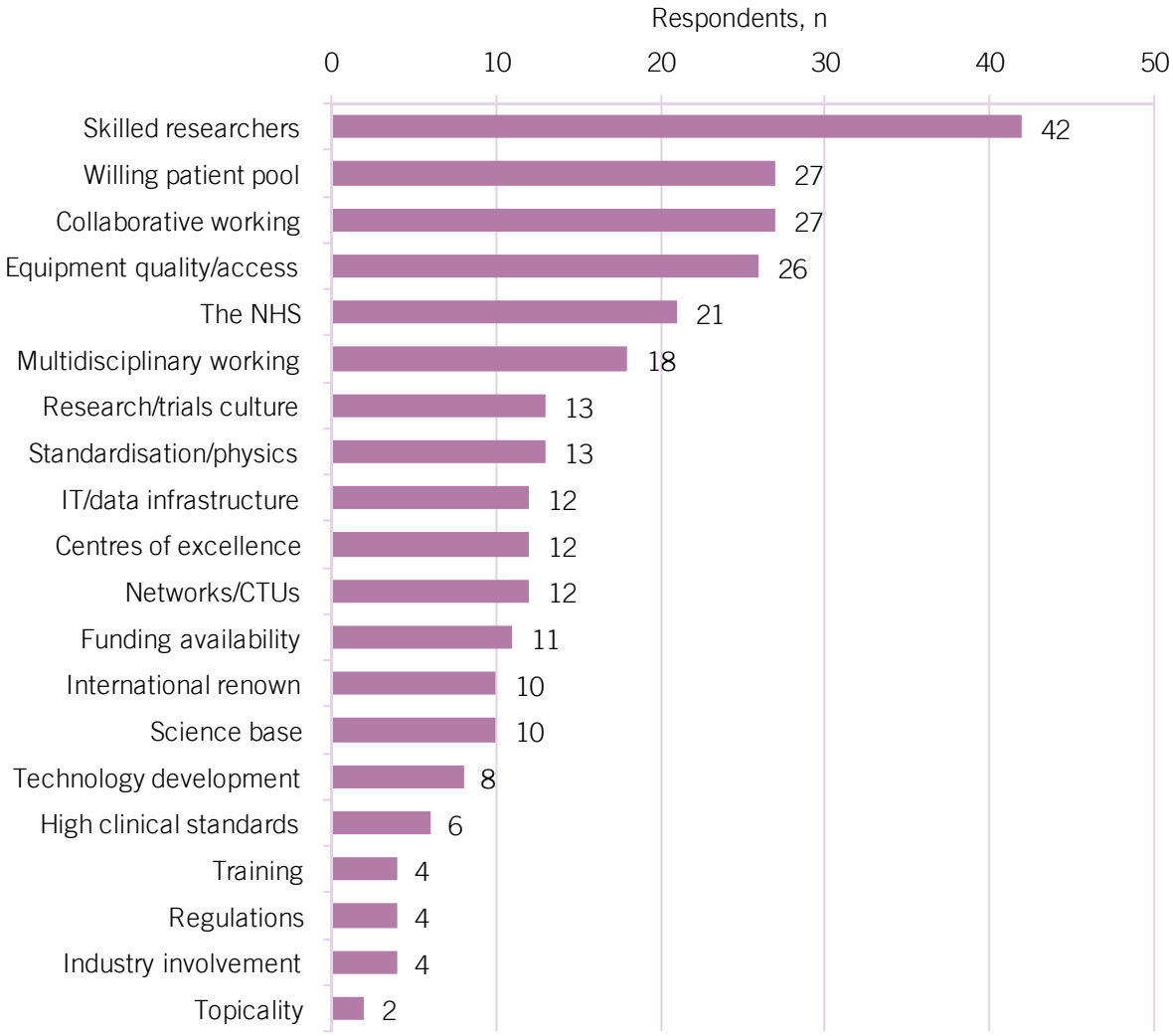
Ways in which respondents use imaging in their work
(N=157; categories were predefined, multiple answers possible per respondent)



*Reponses in the 'other' category included service delivery, department development, radiation protection, dosimetry, computational imaging methods, image reporting, data analysis methods, cost effectiveness, and patient experience

2. Strengths

125 evaluable free-text responses were received on strengths; blank boxes or responses such as 'I don't know' were classed as unevaluable and excluded from the denominator. Evaluable responses were grouped into retrospectively assigned categories following manual review of content, to draw out recurring themes. When answers covered multiple points, they were included in multiple categories.



Summary of strengths

The presence of skilled researchers was the most frequently mentioned strength, and a number of respondents felt that the UK has a strong heritage in imaging and is internationally leading. The investments that have been made in high quality imaging equipment were also frequently cited as an advantage.

There was enthusiasm for the NHS as a delivery vehicle for clinical imaging research, particularly when coupled with the UK's complementary research infrastructure such as trials networks and CTUs. The possibility of recruiting large numbers of patients into trials is a strength, with the UK benefiting from patients' willingness to engage with research, and the structured referral routes via the NHS and networks. A number of people commented on the data linkage opportunities that come from having centralised clinical systems, and the NHS Picture Archiving and Communications System (PACS) was often mentioned as a strength.

Attitudes to research in the UK were also rated positively, for instance the clinical trials culture and strength of basic science in the UK. The high clinical standards and professional training were seen as creating a solid foundation for research.

Free-text responses on strengths

"Active community, extensive expertise, internationally recognised."

"Undoubted multidisciplinary clinical expertise and fairly ready access to all aspects of patient care through multidisciplinary team working."

"Centralisation due to formation of Cancer Imaging Centres has made research and translation fast and efficient. Investing in infrastructure posts/facilities enables science funded on project-by-project basis to be developed and evaluated much more quickly and economically – good competitive position."

"We have an excellent portfolio of clinical trials. We should be able to calibrate and standardise machines on a semi-national basis."

"Conducting studies in NHS hospitals gives imaging trials the necessary pragmatic approach for evaluation in practice. It also aids collection of data for health economic analyses and integrates the study of imaging techniques to other tests, such as biopsies, clinical exam and potential marker assessment which are all on the diagnostic/management pathways for patients."

"There are many good collaborations/organisations within the UK and in my region encouraging research, providing resources and bringing researchers together (Scotland) e.g. SULSA, SINAPSE, NEXXUS. There are many highly talented individuals."

"Widespread acknowledgement that imaging modalities have a major role to play as part of an integrated assessment of patients in clinical trials research."

"High degree of altruism among patients in terms of research participation."

"More coordination than many other countries – enables us to punch above our weight."

"Many established networks enabling recruitment of large numbers of well characterised subjects for trials. Recent large investments in ECMCs/CICs by CR-UK/EPSRC etc. + associated multidisciplinary projects."

"Existing structures facilitating multicentre studies and increasing standards, e.g. PET core lab. Other structures and funding streams with an imaging focus (CR-UK Imaging Centres/Programmes; BIDD). Good imaging drive in Clinical Studies Groups... some at least."

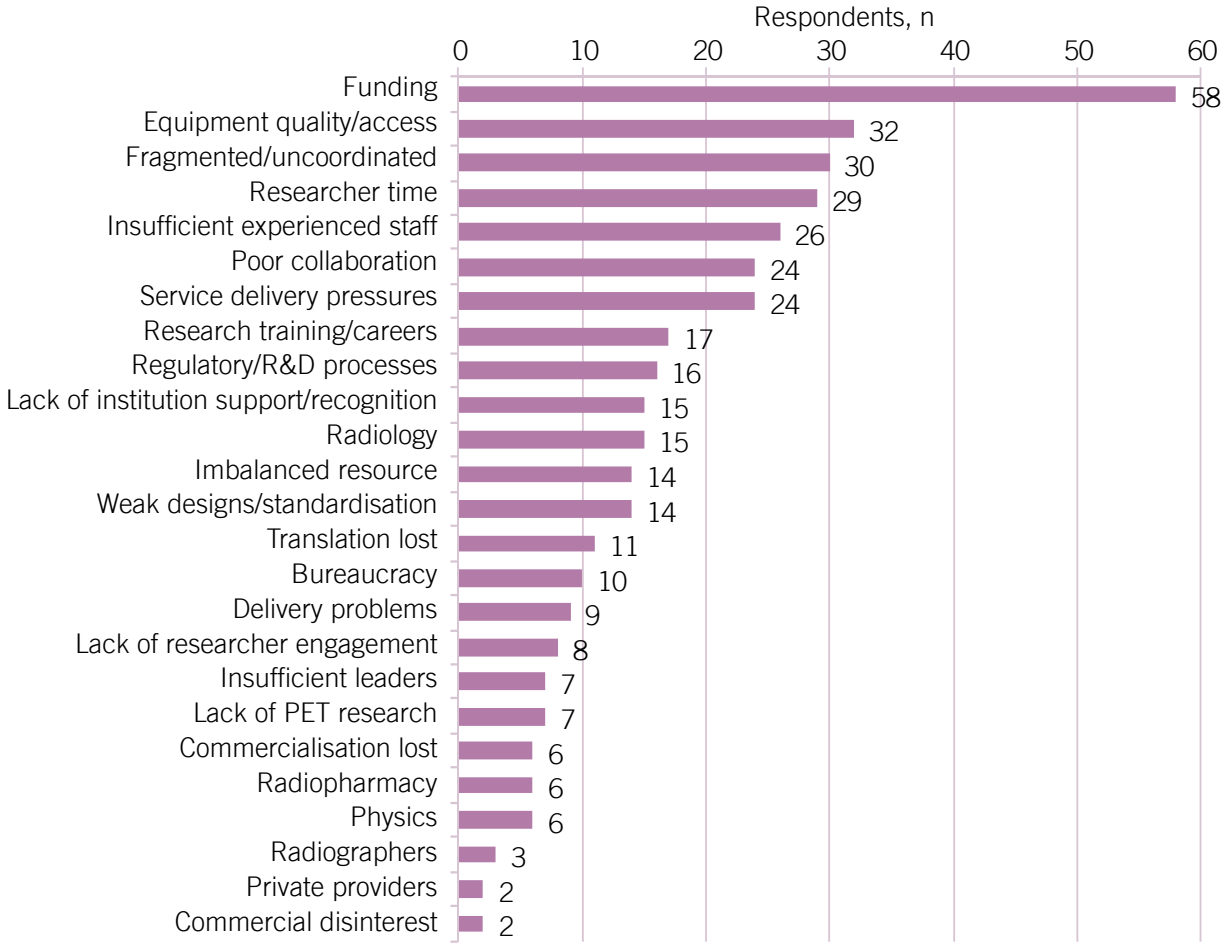
"The UK has some of the world-leading imaging facilities in academia (London, Cambridge, Oxford, Cardiff, Manchester, Nottingham, Leeds, Brighton, etc.) and industry (e.g. AstraZeneca, GlaxoSmithKline or Imanova, Shire). The diversity of locations provides opportunities to reach a wide variety of patient populations and substantial numbers for statistical power. There are also a variety of funding mechanisms provided by the government (e.g. MRC, BBSRC) and from international pharmaceutical/biotech companies who want access to the key-opinion-leaders residing in the UK."

"Medical physics is stronger than in some EU countries and non-research US centres. This is potentially a significant benefit to imaging and to radiotherapy."

"Central review of rare tumours is easily possible now via the image exchange portal. Central review allows for standardisation – thus more uniformity in staging."

3. Weaknesses

130 evaluable free-text responses were received on weaknesses; blank boxes or responses such as 'I don't know' were classed as unevaluable and excluded from the denominator. Evaluable responses were grouped into retrospectively assigned categories following manual review of content, to draw out recurring themes. When answers covered multiple points, they were included in multiple categories.



Summary of weaknesses

Funding was the topic most commonly mentioned as an area of weakness, not so much due to an absence of opportunities to apply, but rather from the high overall costs and the challenges of meeting them at a local level in the NHS. Specific shortcomings included gaps in funding for underpinning or research-enabling work, and difficulty securing funding for translation of basic research into clinical application. It was also felt that the high costs of imaging trials had led to smaller studies, sometimes underpowered, being more successful at achieving funding than more ambitious applications.

Research capacity was a dominant theme, with many feeling that despite investments in NHS imaging equipment, high (and ever-increasing) clinical workloads stand in the way of research – both in terms of staff time and access to imaging equipment for research.

Fragmentation came up frequently as a weakness, in a number of contexts. Examples included competition for funding between groups preventing collaboration, a lack of communication between disciplines and between researchers working on different imaging modalities, and a lack of centralisation of processes and protocols. A number of respondents mentioned the imbalance of resource between centres as a weakness; the few centres with high level funding, and the many without.

Respondents from radiology, physics, radiography and nuclear medicine all expressed views that there were ways for members of their discipline to contribute more fully to research if time pressures were lifted and training opportunities increased. Radiologists in particular put forward strong views that they were seen as a service provider rather than a partner in research, that progress was hampered by an overall shortfall in academic capacity, and that there is a lack of research training and culture in their specialty.

Free-text responses on weaknesses

Funding:

"Funding fragmentation: there are many bodies that fund imaging research, like for example NIHR, some Research Councils and the Wellcome Trust. The areas covered may however be different and non-overlapping. This leads to gaps between funding, resulting in some good projects never succeeding in getting any financial support."

"Tendency to fund imaging capital equipment, but not all the running costs, leading to pressure to give up research time for NHS patients."

"Funding bodies do not support incremental work; this leaves many projects undercooked at the end of a particular funding round. Too much competition for the same funding between groups that have shared interests – this hinders discussion amongst potential partners."

"Strong networks that could facilitate and engineer developments in these areas (NCRI, ECMC, clinical research facilities) but they do not have funding to facilitate developing and generalising tools, methods, QA and training. This sort of funding is also not prioritised by research funding organisations as it is enabling rather than core research activity. This is a key shortcoming."

"The costs and effort involved in performing a trial with advanced imaging are often not appreciated, let alone funded, so such activities are often poorly funded (hand to mouth). Where funding is available it is often sequestered by the NHS organisation with no return or staffing to support the specific activity. Such staffing would not be prioritised against acute service needs."

"Complicated and variable application of research funding arrangements within NHS."

"Lack of integration/communication between R&D departments in different trusts. Lack of clear information on sources of funding."

Interdisciplinary/intermodality divisions:

"Often no communication between the different disciplines and no mechanism for translation into clinical practice."

"Radiology–nuclear medicine divide – now the field is moving towards multimodality (e.g. PET/CT/MRI etc.) the nuclear medicine and radiology professionals need to make a plan for how to constructively deal with this for future proactive dialogue and training etc."

"Boundaries/competition between imaging disciplines and between different professions. Imaging often just seen as a service."

"A lack of communication and involvement from the PIs and the CIs with the imaging department. No feedback on the purpose of the study, what is required from imaging, and the outcomes. Lack of recognition of imaging dept's role in research."

"Segmentation of academic and NHS activities precluding the leverage of key resources to promote clinical trials and imaging development. Silo mentality of many of the imaging modalities and their scientific support groups."

Inter-organisation divisions and imbalance of resources:

"Too few research centres with imaging research infrastructure and patient access. Putting all our eggs in 4 baskets [CR-UK/EPSRC imaging centres] starves smaller groups, often with good patient access, of opportunities."

"Funding concentrated in London and South East."

"Imaging in the UK particularly in PET imaging is very fragmented, with several new and emerging centres (Imanova, Edinburgh, Manchester, Cardiff) with others being sought. Significant investment is needed for high-end imaging (cyclotron, radiochemistry, cameras), and with limited funding this results in under investment within centres and low productivity. There is a strong case for better coordination with such centres seen as regional or national resources. The high cost of these centres is only justifiable if then produce methods and research that impact the wider imaging community."

"Organisations work essentially independently of each other, coming together rarely for very specific projects. There is a lack of communication and lack of sharing because it is not in the financial interest (or publication interest) of groups, causing inefficiencies in productivity. This compartmentalisation also restricts the sample size of studies, making each study sub-optimal."

"Complete lack of drive or support for centralisation of facilities and expertise (i.e. image analysis, radiopharmaceuticals)."

"Very few centres have access to the full range of technology and support services and systems to take forward research."

Academic radiology:

"Academic radiology (together with other relevant disciplines such as academic pathology) remains woefully below a critical mass for success across the UK. There are beacons of real excellence (ICR, UCL, Cambridge, Manchester etc.) but we desperately need a better research career for the academically-minded radiologist."

"Lack of research-trained ACADEMIC radiologists; most research is done by non-radiologists who lack training in anatomy and physics as well as medicine and observation required to undertake efficient imaging research, especially in something like cancer. Radiology lacks opportunities for research training and is much worse off as a consequence than other hospital-based disciplines."

"Lack of importance given to research in radiology training – not core to training no matter what the college states."

"A paucity of radiologists within the system to fill NHS posts has suppressed the time and interest in radiologists in training going further into R&D."

"The usual boundaries amongst staff of not realising there is funding available for research, lack of confidence and knowledge in writing a proposal, lack of protected time, shortage of mentors etc."

"Lack of availability of radiologists who are interested in reporting standard imaging studies to research endpoints and where the primary reason for the scan is investigative."

Research culture and recognition:

"Low expectation for consultants to be involved in research, which is made worse by their lack of training."

"Radiology is seen as service provider rather than full partner. Many protocols are developed without proper radiology input. Academic imaging units are still far and few between."

"The research that they [radiologists] are involved with is mainly diagnostic and therapeutic evaluation and their personal interest in this is often low, as it does not bring any recognition for their work. Leadership in imaging research would offset these disadvantages to a degree."

"Not clear that imaging gets appropriate academic credit OR remuneration transparency."

"Dual PI not the norm for funding bodies."

"Radiological involvement is not being sought on commissioning panels such as NCRI, HTA etc."

"A lack of understanding in diagnostic imaging departments of the need to prioritise research and to take part. A lack of understanding in the same departments that they are entitled to remuneration for the imaging research they take part in as per the NIHR excel sheets which detail the exact charges an imaging department can impose on those who use its services for research."

"Lack of appreciation of the potential of radiology research by other disciplines."

"A belief, sometimes, that we in the UK know better than others. Lots of good imaging research in going on continental Europe and the US, for example, that we aren't always exploiting because we stick to our own ideas."

Research capacity:

"Massive radiologist workloads from clinical service – no time for R&D."

"Individual staff can be under too much pressure (particularly support scientific staff) from service demands to be able to deliver and support research activities (e.g. new radiopharmaceuticals, translating new research developments in to clinical tools)."

"NHS R&D departments have routinely failed to reimburse Radiology for time spent on R&D and as a result there is a major schism between these two areas. Contrary to many clinicians' NHS job plans, radiologists are routinely now being employed with 80–85% of their working time committed to direct NHS service delivery."

"Lack of research active radiologists is a major continuing problem, particularly as the demands increase and the service demands increase. Lack of research training capacity for physicists, radiochemists etc.; shortfall in experienced staff."

"Individual sites at, or below, critical mass in terms of physics support and research time for clinicians."

Failure to leverage clinical/commercial benefit from research:

"Research groups are often based on technique and not answering clinical questions using whatever technique is required."

"More work and investment is needed to follow through innovation to commercialisation arising both within the NHS and within academia. NHS needs to be much more friendly to home grown industry and encourage innovation."

"Funders only progress possible methods/products to pilot study stage."

"Physics research is being severely curtailed at present. This is particularly true in radioisotope imaging. There is little scope for research within the NHS by its highly trained clinical physicists, despite the willingness. As a result, basic research is not being translated into the clinic."

"Lack of support to translate innovative software for new analysis to robust platforms that can support research at multiple centres (cannot leave to industry as industry is to slow and the software is closed box – hard to establish what it does). This is potentially a synergistic opportunity between academia, NHS and industry, but it needs a support mechanism)."

"Teams are smaller than US and Asian groups and do not easily translate innovation into practice, essentially a manpower limitation."

Trial design and delivery:

"Too many small clinical studies that don't meet standard (e.g. STARD) criteria and (because they are so small) have inadequate statistical power. Multi-centre studies too large and expensive so they don't happen very often."

"Large numbers of researchers chasing grants for small, underpowered studies."

"It takes an extremely long time to get a clinical trial of novel imaging started – the hurdles are massive, NCRN funds are not readily released even for portfolio studies by the CLRNs as imaging studies are so expensive. If imaging studies are deemed important despite their cost, then that message needs to go out to the networks who ultimately pay for the scans."

"Although there are many studies incorporating novel imaging as research end points there have been very few where validation of imaging has been a focus."

Standardisation:

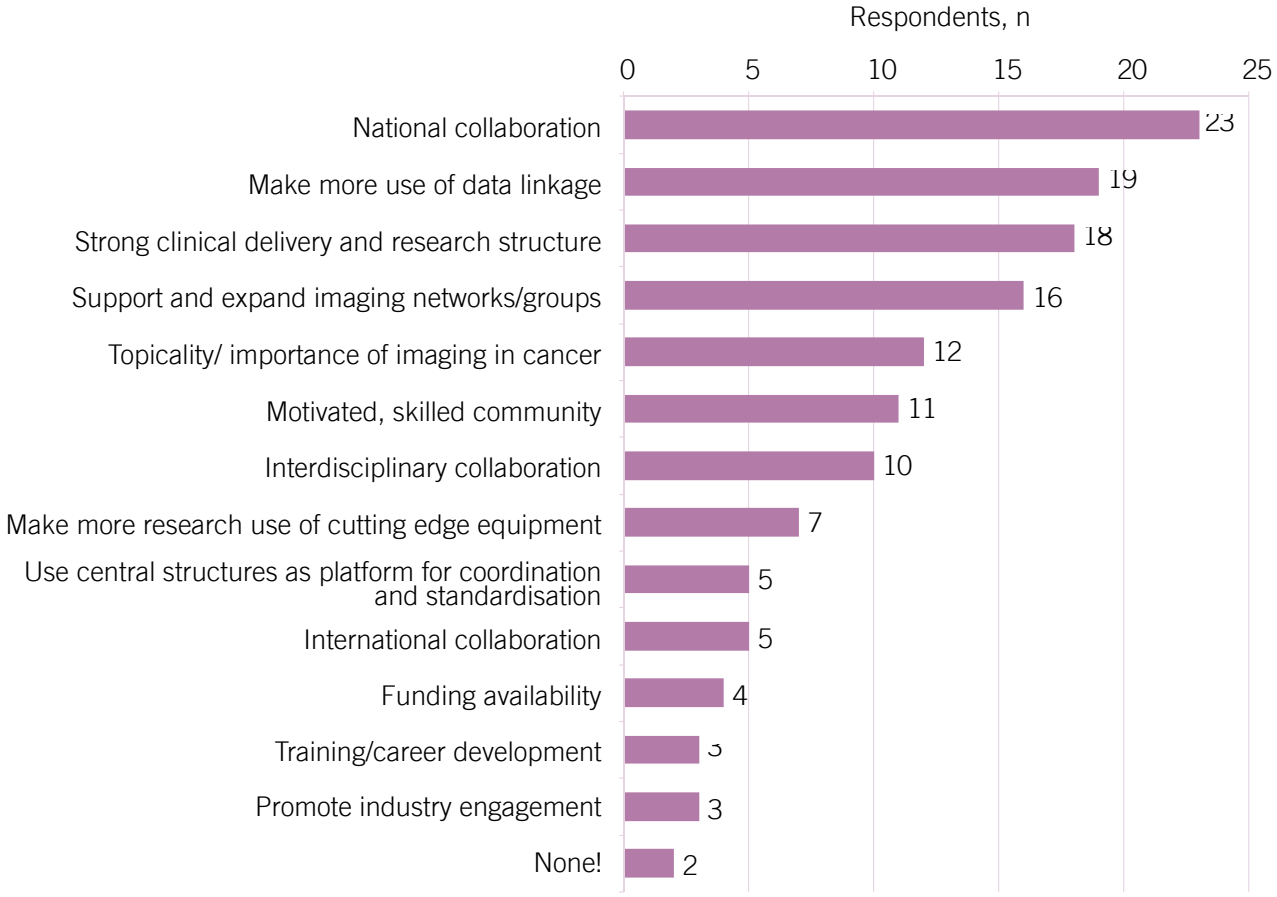
"Need for QA expertise for consistency of scanning techniques."

"Need tumour measurements as standard. Reports need to understand criteria for response / progression in trials."

"Limited systematic assessment of cancer results. Poor compliance with RECIST criteria in general reporting of imaging for cancer."

4. Opportunities

98 evaluable responses were received on opportunities; blank boxes or responses such as 'I don't know' were classed as unevaluable and excluded from the denominator. Evaluable responses were grouped into retrospectively assigned categories following manual review of content, to draw out recurring themes. When answers covered multiple points, they were included in multiple categories.



Summary of opportunities

Although expressed in a variety of ways, there were really two main themes in opportunities: Encouraging research groups to collaborate with each other on topics of shared interest; and tapping in to the good infrastructure we have in place for clinical imaging, data transfer and clinical trials in cancer.

People were in favour of having structures that allowed imaging researchers to work together more closely, and finding ways that collaborative efforts could be incentivised. These comments were generally from the clinical arena, as basic science was seen as needing space for innovation and ownership of ideas. There were a number of calls to avoid duplication of effort by centralising core activities such as QA, radiopharmacy, and training opportunities.

Many saw the strong clinical trials heritage in the UK as an opportunity for taking forward clinical study of imaging advances, with the potential to make far greater research use of the advanced technology that is already in place for imaging. Respondents also saw huge opportunities arising from PACS, with the images stored being a huge resource that, with the appropriate governance, could be very valuable for research purposes. Having standardised protocols and common software tools for acquisition and analysis was considered important to enable multicentre work delivered through the NHS.

Free-text responses on opportunities

Collaboration:

"Cancer imaging centres have built up strong platform for further development – capacity for rapid development evaluation of new science derived from large centres. By working with other institutions with a smaller cancer imaging activity, these centres can build strong networks. Imaging is a relatively basic science that crosses between medical areas of which cancer is just one – cancer imaging has much to learn by working with other disciplines, and vice versa."

"Collaboration in UK and within Europe essential to compete with major US centres, bearing in mind that we are funding-depleted compared with N America."

"Joining together units and sharing expertise. Creating 'centres of excellence' but enabling these to transfer experience to other sites for multicentre trials – so possible centralisation of radiopharmacy or the creation of key hubs around the UK, medical physics experts liaising across several sites and not limited to primary employer (hospital)."

"Due to the way cancer care is delivered in the UK there is a huge potential to conduct large meaningful studies in all cancer types. There is a large untapped interest in many centres to support national imaging studies. Royal College of Radiologists, ECMC imaging group etc. allows good networking for potential national initiatives."

"Create financial incentives for wider collaboration. Support consortia with critical mass across chemical, biological and medical disciplines."

Making the most of data linkage:

"Research opportunities increase via image exchange for rarer tumours. This hopefully is in the patients' interests. EORTC have an imaging platform that works, and that model could be easily adapted to the UK?"

"Have accessible image database with anonymised images and clinical data from both NHS and research studies. To aid this, allow research organisations to use a version of the NHS PACS system – this cost a lot of money to develop and would be very useful for University and other research organisations to store and transfer image data."

"Centralised research outcomes database is a stone's throw from the NIHR / CCF's Portfolio database; research opportunities using a future, universal electronic patient record."

"The images stored on PACS are a huge resource that could be investigated. Trusts with similar imaging could work together on research."

"Large numbers of patients are scanned in the clinical environment. Good clinical and pathological correlation is often available."

Opportunities to standardise and work across sites:

"Development of standardised protocols and software tools within the UK both for acquisition and analysis."

"The coherence and standardisation across the NHS should provide an excellent platform for developing and evaluating novel imaging based technologies. It's getting better with the NIHR but we still have a way to go. Development of common, validated imaging software platforms to ensure good ideas progress along the translational pipeline."

"NCRN / ECMC present superb opportunity for multi-site studies and collaboration. NHS provides great opportunity for standardisation of techniques and technologies."

"Develop a structure for cheaper, larger multicentre imaging studies."

"Opportunities for assessment of imaging biomarkers in NHS practice for relatively low cost of small additional imaging protocols plus centralised analysis and QC."

"The UK has the potential to set up large, multicentre imaging trials to validate imaging-based biomarkers for tumours. Our academic competitors would struggle to obtain the number of subjects for rarer tumours."

Other comments:

"Recent reforms instigated by the NIHR have allowed several junior posts in clinical radiology aimed at junior researchers – clinical radiology now has a cadre of junior researchers "coming through". There is an opportunity for them to correct the deficiency noted in the paragraph above, in the future."

"Continue to proactively engage with regulatory authorities in honing appropriate legislation to enable PET imaging availability/capability."

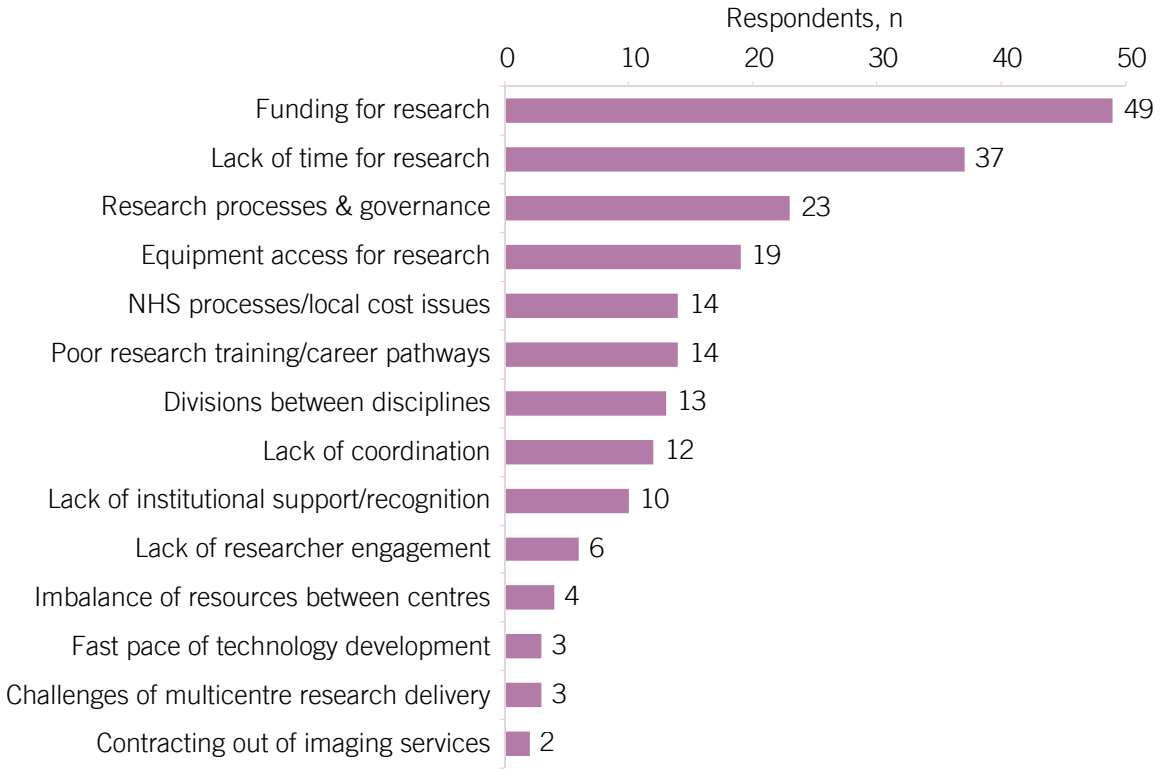
"Many research techniques, e.g. CT/MRI perfusion, whole-body MRI are available on standard equipment, but are currently underutilised."

"Wonderful opportunity for correlating and integrating imaging (esp. functional imaging) and molecular biomarkers."

"Extend/continue excellent imaging initiatives such as the CR-UK/EPSRC/MRC/DH funded imaging centres and programmes."

5. Barriers

119 evaluable free-text responses were received on barriers; blank boxes or responses such as 'I don't know' were classed as unevaluable and excluded from the denominator. Evaluable responses were grouped into retrospectively assigned categories following manual review of content, to draw out recurring themes. When answers covered multiple points, they were included in multiple categories.



Summary of barriers

The barriers overlapped significantly with responses given under 'weaknesses'. Funding for research was again the most prominent issue, citing issues including the high overall costs of imaging, difficulty competing against 'cheaper' studies, and gaps between funding streams.

In the clinical setting, lack of time for research and access to equipment for research purposes were also key barriers. Several mentioned the need for out of hours research, and some noted that the pace of technology development itself presents a challenge, meaning service developments take priority over research.

Process issues featured heavily, both in terms of slow and labour-intensive regulatory procedures, and difficulties in the relationship with R&D departments and covering the NHS costs of research. Some questioned whether GP-led funding would pose an additional risk in this regard.

There was a further cluster of barriers that centre on difficulties working across disciplines, and a lack of research culture, predominantly within radiology. This was seen as being in parallel to or as a result of inadequate research training and experience, a lack of institutional support for participation in research, and a lack of academic recognition for radiologists for their part in the process.

Free-text responses on barriers

Problems accessing research funding:

"Lack of interaction and coordination between the different funding agencies."

"Competition for funding with non-imaging science (we are perceived as too expensive)."

"No funding mechanisms for enabling developments... building on research, but pre-commercial. No funding streams for coordinating networks to access to build supporting capacity. Lack of appreciation of the complexity and multi-factorial support needed for advanced clinical imaging research."

"CR-UK/EPSRC initiative has significantly bolstered activities and capacity, but future continuation not clear. Failure to build on this could set imaging back considerably."

"CR-UK & EPSRC Cancer Imaging Centres initiative. Assuming that these centres can cover most aspects of cancer imaging has been damaging. It would have been better to support good research where good research was underway rather than try and drag everything into these centres. PET research was not previously strong in each of the centres and they've wasted a lot of time trying to establish PET research while other centres with established programmes have suffered."

"Difficulties obtaining funding for clinical research, partly arising from apparent lack of clinical imaging expertise on the part of funding bodies and some of their committees."

"Research granters often unwilling to fund methodology, expecting that to already be provided by MRI manufacturers. Little quantitative software provided by manufacturers."

"Imaging studies are relatively expensive (£600 per hour for MRI, PET c.£2000!). Imaging research is not sexy molecular biology. The grant committees will rarely have an imager on and they don't understand what we are doing. Even the CR-UK BIDD committee has very few imagers on the board."

"Relatively few funding calls specifically for imaging."

"Damaging gap in funding from proof of concept to CE marking and initial clinical trial."

"Threat of downturn in funding of 'responsive mode' projects by EPSRC. EPSRC funding has been incredibly successful at ensuring good ideas with a practical application are funded early stage. This role is now threatened by funding restrictions (EPSRC's red–amber–green trafficlighting of different topics/areas of research."

Research capacity:

"Time – the reporting of research imaging is usually in addition to usual workload. The latter of which increases year on year."

"Colleague expertise – relatively small group, even in a large teaching hospital, with the time expertise and inclination to get involved."

"Training schemes do not seem to encourage/enable clinical fellows in e.g. nuclear medicine – extremely small number of senior nuclear medicine trained physicians."

"Insufficient academic training positions leading to a lack of radiologists intending to do research."

Labour-intensive processes:

"Unwieldy research governance processes, which have not been designed with imaging in mind."

"Difficulty in setting up and running clinical trials – the regulatory aspects are greater than other types of clinical research (need for GMP manufacturing licences in radiopharmacies, need for additional regulatory hurdles and overview)."

"Ever-increasing overregulation in every part of UK life is having a real effect slowing down research and increases administration costs. This is already having an effect on UK competitiveness and will make it increasingly difficult for us to maintain International leadership."

"Complexity and onerous requirements of clinical research governance and procedures, quite out of proportion for many studies where the imaging is essentially observational."

"Obtaining agreement for studies from local R&D and ethics committees is time consuming and this effort is presumably being repeated many times and inefficiently around the country."

"Finding patients for imaging methods development studies is time consuming. Data access, anonymisation, obtaining clinical reports/histology for imaging correlation are all time consuming."

"The time and effort involved in coordinating or participating in multi-site... anything. How can we construct a public-domain database of clinical imaging data when no one has the time to set it up or publish in it? How can we provide incentive for scientists to make their software open source? How can we bring together networks of imaging core labs in order to maximise sample sizes? Where does the money or extra staffing come from to facilitate this extra level of interaction?"

"Ethics getting more and more complicated so patients don't understand the patient information sheets or want to read them, as longer and longer."

Delivering research within the NHS:

"Hospitals need to think in a more integrated manner. Ethics is perceived as difficult and R&D support is in some trusts obstructive rather than helpful. IT is uneven and again some trusts are helpful while others are frankly obstructive, interpretation of governance rules seems to be a local rather than national issue."

"Lack of consideration of research in most procurement and commissioning processes."

"Much primary imaging research is not funded as it is classified as a "treatment cost" – we need to address this with the DH."

"GP Commissioning could stop access to expensive but essential imaging techniques. If GPs are given easy access to information on research being conducted then this should pull down some barriers."

Lack of collaboration:

"Silos between many different schools of research (e.g. Informatics, Medicine, Engineering, Chemistry)."

"Resistance to working across disciplines. Working as a team is difficult to reconcile with post-docs' needs for first author papers."

"Slight difficulty in oncologists following radiologists' lead in the most appropriate advance technique."

"Relatively poor inter-professional working both within clinical radiology departments across staff groups, and across clinical teams; despite the centrality of imaging examinations to patient management clinically, this is not always supported by good cross clinical team working."

"Academia and industry find dealing with the NHS difficult. There is no 'front-door'."

"There appears to be a widening gap in hospital based imaging within radiology and nuclear medicine departments and imaging within academia, driven by different objectives. This limits the translation of novel research into clinical practice."

"No long-term vision exists for imaging research in the UK. No long-term evaluation of the commercial or health opportunities have been performed or at least published. Again look at our European colleagues for insight."

Lack of research culture and institutional support:

"Funding for trials is available but difficult to access without experience and track record. There is no desire or funding likely to be had for a centralised committee offering advice and support."

"Lack of an imaging training programme across the profession; all done by individual deptartments. Need transferrable skills."

"Lack of recognition – much time and effort is put in to imaging research as a radiologist, but only very rarely with any recognition in terms of publications."

"Managers see training income as more lucrative than research activity and assign research activity to a lower priority in our institution. The pressure is to recruit large cohorts of students and maximise the quality of their experience. Research is recognised as useful but only if it brings in funding."

"Lack of research culture in radiology. Lack of interest in other specialties in supporting imaging research."

"Lack of interest in/engagement with research from professional organisations – for whatever reason. Situation is very different in many other countries. Complementary lack of engagement with clinical imaging from many research groups."

Technology:

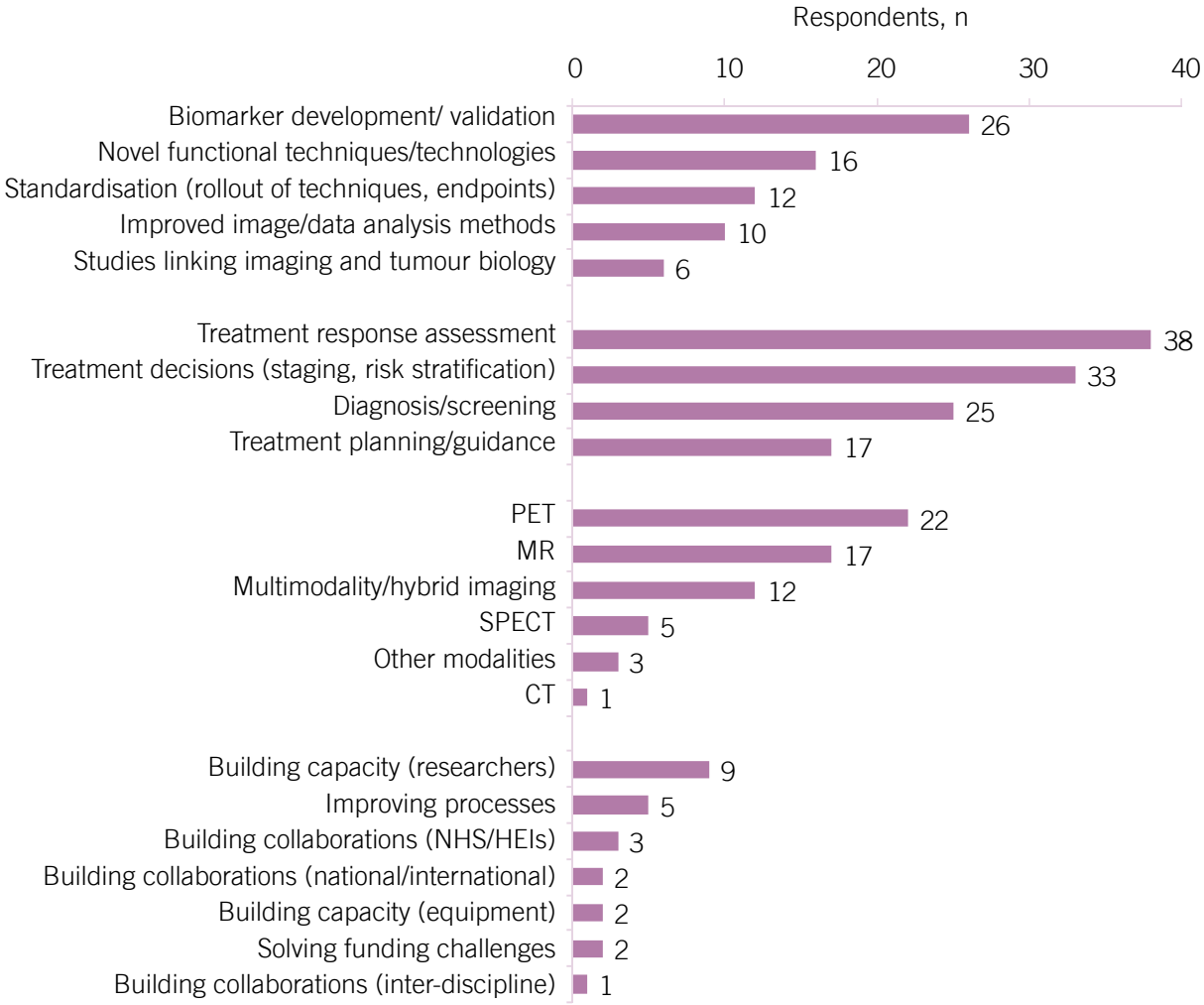
"Differences in technology used by various equipment manufacturers leads to challenges in standardising imaging across centres."

"Speed of technological development can be inhibiting (so service developments and the implementation of new techniques/technologies tend to take priority over research)."

"Most imaging research investment is in development of novel approaches that evolve with emerging technology. This means that yesterday's technology is yet to be validated against standard treatment paradigms."

6. Research priorities for the next decade

122 evaluable responses were received on priorities; blank boxes or responses such as 'I don't know' were classed as unevaluable and excluded from the denominator. Evaluable responses were grouped into retrospectively assigned categories following manual review of content, to draw out recurring themes. When answers covered multiple points, they were included in multiple categories.



Summary of research priorities

As would be expected, there was a wide variety of responses to this question, and details are given in the free-text responses below. Responses have been clustered as above into general topics, stages of the patient pathway, modalities, and process issues.

The most frequently cited priorities were about development and validation of imaging biomarkers (for assessment of disease status and assessment of treatment response), and standardisation of techniques for their determination.

A number of respondents expressed a desire for greater use of quantitation in imaging, and a need to standardise protocols and analysis tools in order to provide the kind of rigor that makes research clinically useful. Several mentioned opportunities for correlation of imaging data with pathology markers.

PET and MR were the most commonly mentioned individual modalities, with support for multimodality imaging. Some spoke of ambitions to refine the current technologies, such as increasing sensitivity, focusing on non-ionising imaging, and improving motion correction.

Free-text responses on priorities

Quantitative imaging:

"To bring quantitative imaging to the forefront of research. This is key when making objective decisions and opens up imaging research to those beyond radiology."

"Establish quantitative methods as routine clinical tools."

"Quantitative imaging with PET and SPECT. Both modalities are increasingly being used for radiation therapy planning, for which quantification and partial volume corrections should be essential."

Standardisation/quality

"Development of robust imaging biomarkers requires access to state-of-the-art hardware and agreement on acquisition and analysis methodologies. Preferably using maintained and developed standard analysis tools that are distributed to interested sites so that we can develop a body of evidence using standard protocols."

"Functional imaging for sure. But some standardisation of diffusion-weighted imaging with MRI needs to occur before this is widely used. Ditto for dynamic contrast-enhanced MRI."

"Promoting standardised imaging for staging – in close collaboration with manufacturers of MRI equipment to allow seamless movement between staging and treatment."

"RECIST automation / response automation – central review facility for trials."

"Standardisation of clinical imaging and reporting techniques to allow comparison to image and outcome data from trials and to allow translation of techniques developed in one centre to be translated to others."

Early diagnosis/screening:

"Low-cost, reliable and easy to use imaging technologies for use in GP surgeries for early diagnosis and where applicable for screening. Earlier diagnosis of cancer will have a dramatic impact on cancer outcomes and survival."

"Research into lung cancer screening as the outcome hasn't changed for years."

"Using low-dose CT as a screening tool."

Staging/treatment selection:

"Improve staging to minimise futile radical treatment (viz PET-CT in lung cancer and PETNECK type trials)."

"Imaging that improves treatment choice i.e. determine un/suitability for a specific treatment (even better if NICE approved). This also ensures improved spending/ funding on treatment which the NHS have to rationalise and prioritise."

"Better characterisation, including biobanking, of subjects entering research studies."

Assessing treatment response:

"Development and qualification of effective image biomarkers. Uptake beyond RECIST is depressingly slow."

"Rapid assessment of treatment response - possibly on a personalised basis, i.e. do not wait 6 months for a follow-up, it might be in a few weeks. Could prevent use of ineffective treatments (drugs and surgery much more expensive than imaging). Novel PET or MR techniques might be used here to look at cellular changes."

"Markers of early response to targeted therapies. They don't tend to reduce tumour size (i.e. routine criteria of response) rapidly and are very expensive. If we could tell within a cycle or two if it was working, it would save cost and allow consideration of other treatments for the patient."

"Integration of functional imaging biomarkers – especially in the context of predicting treatment response (or its flip-side, resistance). In an era of more and more expensive systemic treatments and with an appropriate emphasis on minimising unnecessary toxicity, it is more important than ever (on both humane and health economics bases) to appropriately select treatments for individual patients."

Radiotherapy planning:

"New functional imaging technologies for delineating the target volume to be treated and that have improved tumour characterisation and profiling capabilities. More powerful functional imaging systems that allow the development of adaptive treatment plans, tailored to each patient, and the assessment of the tumour response to treatment will make the management of the disease more streamline and cost-effective as well as increase the throughput and reduce the overall burden on the NHS."

"Reducing margins in radiotherapy and dose escalation in radiotherapy."

"New advanced technologies for imaging tumour motion. These new systems will increase precision in targeting the tumour using radiotherapy, increasing the local control rate and reducing toxicity."

Treatment guidance:

"Image guidance of novel therapies – aimed at reducing risk compared to surgery, or more effective removal of malignant tissue and sparing of healthy tissue."

Refining techniques and technologies:

"Enhanced detection and characterisation of smaller volume disease through ligands and image-able tumour markers."

"New imaging technologies for long-term patient follow-up. Long-term patient follow-up will allow more effective management of late side effects and second cancers."

"We need to transition to whole body imaging assessments [MRI]. The radiological paradigm of diagnosis, staging needs to change. This will require a development in enabling technology; this should be a focus for future developments in imaging."

"Personalised risk stratification... will require more sensitive imaging at staging and evaluation of tumour biology in vivo. This will require developments in MRI and PET imaging (MRI/PET devices)."

Comments on modalities:

"There are big opportunities for imaging to contribute to personalised cancer care, primarily through multi-parametric quantitative imaging. This can be achieved through pre-treatment risk stratification and more specific assessments of treatment response. Hybrid devices (PET/CT, SPECT/CT PET/MR) will be particularly important to make multi-parametric imaging available from a single examination."

"MR screening/follow-up, especially for situations where the cumulative CT or PET dose is a problem."

"Develop and validate a handful of PET/SPECT tracers that can significantly improve diagnosis and monitoring of treatment. Because investments have been made in the scanners and other infrastructure, but the utility of the techniques are limited by lack of available tracers applicable to large patient populations."

"PET/MRI must be the ideal modality of the future – combining function with anatomical imaging. Role of ultrasound contrast agents for anti-angiogenic drugs?"

"Increase use of MRI for tumour response assessment, especially with antiangiogenic therapy."

"Implementing the "advanced imaging techniques" such as whole body diffusion for assessing metastatic bony disease instead of meaningless use of CT and bone scan which do not assess metastatic bone response."

"Functional (perfusion, diffusion, elastography, BOLD...) and molecular imaging (TEP tracers, MRI cell tracking...) in a QUANTITATIVE and standardised way."

Principles to underpin research:

"More well-powered observational and interventional clinical trials (ideally multicentre)."

"Need to properly validate new imaging biomarkers - what are their limitations as well as uses?"

"Comparisons between patients, for a patient over time and between drugs and therapeutic schemes require reliable numbers."

"Many new imaging techniques have recently become available e.g. PET, DW-MRI but there is a relative lack of evidence of clinical usefulness. Often patients get multiple tests, the incremental value of some is limited."

"Funded strategy for proper validation of biomarkers for multicentre use. Strategies for integration of advanced imaging methods into clinical practice. Massive collaborative efforts (if we wish to be in any way competitive."

"Imaging should be an integral part of every grant application and medical schools and universities MUST recognise the importance of supporting imaging (including personnel as well as technologies)."

"Consolidation of the large number of candidate methods (e.g. PET tracers, but also MRI methods) and focus on development of a panel or robust, validated and clinically useful imaging biomarkers."

Enabling steps to support research:

"Developing improved access to PET for a range of cancers."

"Robust supporting IT platforms that talk to each other."

Other:

"New use of existing technologies – there is so much to learn about what we already use (i.e in the MRI arena there is functional MRI, kinetic MRI as well as new sequences which delineate different tissues)."

"Tissue characterisation with molecular and genomic profiling / correlation."

"The use of very specific molecular biology biomarkers: test whether it is feasible to develop specific imaging tracers for evaluation of molecularly targeted drugs. Can this be done in the required timeframe and is it cost-effective?"

"Emerging PET/MRI technology is likely to be very important. Not everyone is convinced but simple things like using the MRI to track and correct motion in the PET data could result in a step change in the information within the data."

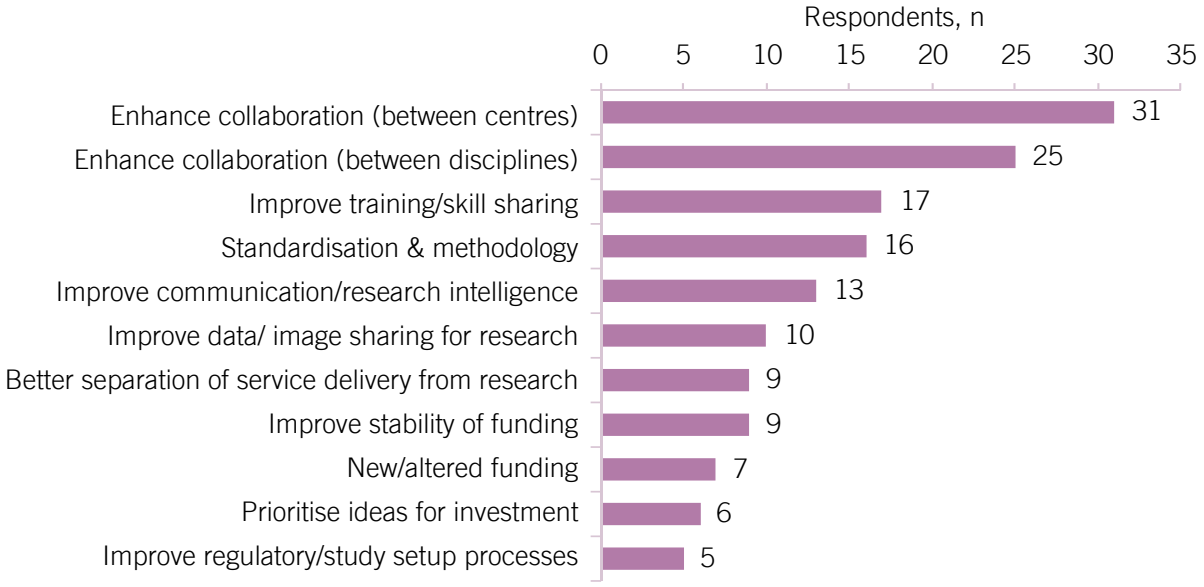
"Understanding the time course of functional imaging during i) the natural history of cancer induction and growth, ii) early response to treatment (drugs and/or radiation), iii) late toxicity."

"Anything that improves quality of service and quality of care in imaging departments, because efficiency and patient experience matter."

"Focus on demonstrating predictive value of existing imaging techniques. Why? Because much of the rest of the world has already started making assumptions about the value, e.g. of FDG-PET. Only the UK is likely to be able to conduct randomised studies to explore the true added value of these techniques. If we're not careful, we'll be dragged into using non-evidence based imaging which will then compromise our ability to develop these techniques to the further benefit of patients."

7. Getting greater impact from existing investments

102 evaluable free-text responses were received on how to get greater impact from existing investments; blank boxes or responses such as 'I don't know' were classed as unevaluable and excluded from the denominator. Evaluable responses were grouped into retrospectively assigned categories following manual review of content, to draw out recurring themes. When answers covered multiple points, they were included in multiple categories.



Summary of ways to increase impact

Collaboration was the most prominent theme. Some people expressed this as a need for national coordination, others pointed to a looser structure of reducing competitiveness between centres and incentivising closer working, for example by funding calls that mandate multicentre working or via existing networks such as the ECMCs. Competition for funding was acknowledged as being necessary for keeping standards high, but also felt to be divisive in its present form.

In terms of working better across disciplines, there were two main angles. The first was that radiographers and radiologists appear to feel undervalued within research teams and may not share the credits of research as they are seldom the PI or first author. The second is about closer working between clinicians and scientists, to bridge the gap in translating ideas into clinical use. Suggestions for improving on the ground support for research included greater use of technicians within radiology departments, and greater involvement of statisticians, particularly to develop and implement quantitative methods in functional imaging.

Respondents also wanted to see the leading imaging centres giving more back to the community in terms of skill sharing, and talked about the need to break down barriers between centres (which is currently hampered by their need to compete with each other). Some felt that the clinical relevance of developments could be increased by broader, earlier collaboration between academic and clinical teams.

Making better use of data was again prominent within responses, with many feeling that with the right standardisation and QA in place, research data should be more widely shared and mined for research purposes. Respondents also talked about ways to drive up the quality and impact of research that is being done now, by developing common protocols, harmonising methods, providing capacity for central review, and setting standards for data gathering. Several saw the potential to 'go the extra mile' with current trials to get more value out of a single piece of research, whether by adding in an imaging question to cancer trials or capturing pathology data in parallel to imaging-led biomarker work.

Free-text responses on increasing impact

Centralise information and core support:

"A share site where interested parties could share their research ideas and/or ongoing projects across the country."

"Central register online? To avoid duplication and to encourage good standards of research design."

"Making everyone aware of research occurring in other departments, which needs to happen regularly and not only reported at study days etc as in the current climate there is no funding to attend study days etc in order to disseminate knowledge."

"RECIST automation / response automation – central review facility for trials will save many hospitals time and QA all outputs."

"Include bioinformatics into this arena as a core support tool."

"Establishment of beacon centres with resources to offer imaging capability across networks."

Harmonise methods:

"Better adoption of standards for image QC and data transfer."

"Engagement with the imaging system vendors to encourage the development of standardised acquisition methodologies and quality assurance."

"Agree common protocols. Arrange central review of trial scans."

"Standardise algorithms, centralise anonymised data including images, for non pharma funded research so that we can all learn from others and improve. Through standardization, meta-analysis is more likely to reveal significant leads."

Pool data for research:

"Provide facilities to upload data sets to central database. See the BIRN project for functional brain mapping."

"Enforce through publication requirements, making suitably anonymised images and associated data re-usable for other developments and trials from which it was originally developed or collected – open source data – while ensuring that data collectors have the first bite of the publication cherry."

"Improved infrastructure for creating and managing image databanks, to include "raw" digital image data where applicable. Could work along the lines of e.g. the Breast Cancer Campaign Tissue Bank."

"Reassess service provision models to consider large scale collaborative data collections with centralised QA and QC, integrated into diagnostic studies as well as trials."

Support skill development:

"Coordination of trials, providing clear guidance on processes to follow including how to fund trials, what has been done, what is a good trial."

"Better academic clinical radiology; I have reviewed several applications over the last couple of years where the basic science is good but it just isn't supported by good academic clinical radiology to form a credible clinical trial."

"We need a structure to train researchers who will be participating in multi-centre trials."

"Support funding applications for more young investigators to set up new research groups."

"Find a way of rewarding members of large collaborations who are not the first or last authors."

"Ensuring imaging skills and understanding at a technical/scientific level is supported as a key and transferable skill set. Development of imaging centres capable of leveraging these skills in novel ways."

"Setting up training programmes and faculty (across sites, possibly national syllabus) for a new generation of PET imaging talent in the UK (across disciplines... could be done in conjunction with other charities/funding bodies?), engaging disciplines or sub-disciplines that are related but traditionally have slightly different approaches and considerations."

Break down barriers to collaborative working:

"Reduce competition and improve cooperation amongst the strongest teams. Set targets for consolidated research."

"Provide incentives for knowledge and staff sharing among rival institutions. Consider informal exchange schemes/fellowships."

"We need a collaborative structure that will allow research radiology groups to collaborate more effectively and (in the current financial climate) cheaply."

"Any coordination would be useful but there is inherent unwillingness to share data due to publication/patent pressures."

"Properly co-ordinated national strategies for imaging. No one UK centre is comprehensive and has an internationally leading pre-clinical + clinical PET, MR and other functional modality track record."

"Cross-'boundary' research, perhaps establishing research academies; broader collaborations between centres / units, and related disciplines, perhaps fostered / partnered with RCR."

"Research co-ordination of parallel programmes, with communication between teams, would reduce the impact of time spent in preparation/ ethical permission etc."

"Research co-ordination to bring together different imaging specialties, creating a broader view of patient management across imaging, rather than confined to a single modality."

"Identifying high value projects, supporting collaborative initiatives."

"ECMC centres should link up with NCRN resources so all concerned are motivated to deliver on the imaging agenda."

"Although a competitive culture is needed to ensure that the best research is funded, often existing resources exist at multiple sites within the UK, with it being optimal to use such resources rather than replicate the resource at a separate site."

"Allow experts in radiopharmacy, radiochemistry, nuclear medicine and medical physics to work across sites – this is a funding issue but also one of institutional barriers. Funding this type of work must include the freedom for centres to collaborate."

"Please go to good teaching UK hospitals and use their skill. If you only work with current academic centres you will get nowhere slowly but get some interesting academic papers. We need real tests for real clinical situations and these are only found in real hospitals."

"Sharing expertise and resources between clinical areas – imaging is not just cancer, the basic sciences behind it are the same as in other clinical areas."

Facilitate translation from basic into clinical research:

"Impact is associated with developing an evidence-base that is solid and ultimately supports procurement decisions that will then pay back industry. So we should aim to move medical device innovations more rapidly to clinical trials. To do this, we need some sort of improved 'front-door' to give industry and University academia access to NHS patients for trials. We might consider setting up a faculty - perhaps associated with NIHR, that can be seen as a pool of expertise in getting clinical trials designed and funded and run."

"More effective translation. Situation is much better than 10 years ago but we still have a way to go. Active involvement of medical imaging industry at the early stage of project development. In particular encouragement of SMEs working with academia to really push thru' innovation."

"Ensuring that methodologies developed in the R&D arena are adequately translated into the clinical environment. Too often the process uses technologies that are not widely available or understood which compromise the clinical utilisation. Ensuring that clinical groups are involved in the R&D activities to ensure above is feasible."

"Foster pre-clinical and translational works in functional and molecular imaging with emphasis on quantification. Develop centres for quantitative image analysis outside of CROs, and including a heavy load of statisticians."

Make sure every trial counts:

"Make tools in clinical trials much more comprehensive and robust to extract maximum information from minimum input data."

"Priority should be given to developments that have greatest likelihood of effectiveness and cost-effectiveness in ultimate clinical practice. A framework needs to be established to enable an estimate of likely effectiveness and cost-effectiveness to be obtained early on in the development of an innovation, rather than waiting to late in the development process as is commonly done currently."

Find ways to facilitate delivery of research:

"Provide specialised technician helps within the radiology department to: select the patients, follow/supervise the imaging schedule, assist the regular technician during the demanding/unconventional functional acquisitions, control the quality of the data and store the data."

"The regulatory environment has increased to the point that early clinical trials (pilot and phase I) are virtually impossible to set up and run – a new imaging agent which may or may not work in humans in vivo still has to go through the same exhaustive regulatory procedures as an agent used in phase III/IV trials. There must be some form of 'fast-tracking' permitted for these early trials, but of course with appropriate measures to ensure patient safety. The current clinical trials processes are too all-encompassing and have become inappropriate for early phase trials."

Improve stability of funding:

"I think we are doing as well as can be expected with the limited resources. Wider availability for imaging programme grants would be beneficial so researchers can concentrate on research for a period rather than spending lots of time applying for funding for each small project."

"Reward good work by continued funding – allow incremental developments."

"Increase its importance in funding streams (for example I know of grant applications where the radiology is removed or reduced to save money)."

"More emphasis on establishing an environment where teams can function in the medium-long term. Funding for the basic team to keep infrastructure going, with shorter term funding for specific projects."

"Get better understanding in NHS of research needs and what support is required. Methods of meeting all the research support costs for clinical trials."

"We also need a follow-up programme after the current imaging centres programme expires."

Ensure equipment is fully used:

"Greater use of current resources. Most equipment is used for less that it could be."

"Through maximising utilisation of research scanners and cooperative working between clinical and research centres to facilitate this."

Promote implementation of results/best practice:

"Dissemination of existing findings to reduce variations in practice which result from local custom and preference i.e. education of clinicians, use of evidence based principles."

"Demonstration of value to NHS and to patients."

8. Areas in need of coordination

77 evaluable free-text responses were received on areas that would benefit from greater coordination in imaging research; blank boxes or responses such as 'I don't know' were classed as unevaluable and excluded from the denominator. Evaluable responses were grouped into retrospectively assigned categories following manual review of content, to draw out recurring themes. When answers covered multiple points, they were included in multiple categories.

Summary of areas for coordination

Given that many respondents had proactively identified coordination as a priority at earlier stages in the survey, there is a degree of overlap with previous responses. Finding ways to encourage multicentre working was the biggest plea, with many commenting on the fact that to get sufficient statistical power for studies to be relevant, this may need to be actively encouraged, in view of the disincentives of competition for funding.

Asking an explicit question about coordination drew out a range of practical suggestions. These included a strong message about developing standards and common practices, and avoiding duplication of effort by providing central sources of information such as details of ongoing trials, methods and protocols. Others advocated coordinating the provision of advice, support and training, and ensuring that imaging representation is built into other groups. Further suggestions can be found in the free-text responses below.

Free-text responses on coordination

Develop standards and common platforms:

"Standardisation of the acquisitions (consensus, expert groups, recommendations). Standardisation of the data processing/analysis."

"Common software development for analysis and data curation. Development within an Open Source framework. Development of transferable image acquisition protocols between manufacturers (the open source MRI scanner)."

"Software is varied and fragmented. I would not recommend funding a single "super" package, rather we need to encourage inter-operability, minimum standards of documentation, input and output formats etc."

"Informatics, it seems every team has their own approach. Image registration is the most common problem for which every group develops a different solution this needs to be taken forward as an open source initiative run independently."

"Tender for centres with appropriate expertise to develop user-friendly tools that allow standardised analysis or can address issues of specific analysis with a view to subsequent deployment."

"Standardisation of protocols to allow pooling of results."

"Measurement techniques. Standards of QA (particularly within-subject reproducibility which often limits the sensitivity of techniques in trials) that can reasonably be achieved."

"Specific funding stream for enabling developments. Some funding through networks such as ECMC to enable common QA approaches and tools, to coordinate protocol development and testing, to provide common software tools for advanced image analysis. Maybe this could be done in a commissioning way to develop specific tools and frameworks within these tools. The CR-UK Centres had a bioinformatics group that made some progress but could go no further (including coordination and use of available industry solutions (partial)) as there was no available funding support for that activity."

"Centralised approvals of use of imaging data for research; get rid of the need for local approvals."

"The sharing and standardisation of: regulatory practice and documentation; research protocols; image reconstruction and data analysis, etc. To achieve this some standards would need to be defined and mechanism found to encourage researchers to share such information for instance by making it a condition of funding. Currently it is in your interest not to share and enable other sites to catch up."

Centralise information and core support:

"A website with all the current projects on them, so the research isn't duplicated but you know what is going on."

"Allowing that some research may have commercial applications or purpose and patient privacy should always be respected, some kind of easily accessible database of active research and methods used would be a big step forward, if only to stop duplicate research in these times of very limited funding. A comprehensive list of research grants and funding agencies would be a big help."

"Access to expert protocols, acquisition and analysis methods."

"Knowledge pool/skills matrix through SCoR [Society and College of Radiographers]."

"Clarity on who pays for what in clinical research – still the case that few understand or agree on who pays what costs in clinical research."

"The development of a comprehensive linked anonymous clinical and image database across the University/ NHS sector would improve the ability to correlate findings from all imaging studies - not just those in specific targeted research."

Joint working:

"Because of the interdisciplinary nature of the field, most aspects would benefit from greater co-ordination, from tracer development, to preclinical evaluation and human studies."

"There is significant overlap in the activities undertaken by those working in MRI, CT and PET. A recent ECMC Imaging Network meeting that brought such people together was extremely useful and many of the attendees expressed a desire to see more of this kind of meeting. Meetings arranged around specific imaging problems faced by PET, CT, MRI & US (and others) would be a good place to start."

"Issuing a challenge to submit collaborative proposals which identify and potentially solve problems in the application of new molecular knowledge for patient benefit using imaging."

"Funding for multi-centre/multi-disciplinary working parties to identity investment needs. Research conducted at one centre does not translate easily to the general community. Research involving SPECT/CT, PET/CT, PET/MRI needs a multi-disciplinary approach. Consultation should be held with bodies other than the RCR, such as IPEM and the BNMS."

"There needs to be better engagement between research imagers and clinical radiologists. For example, some experimental cancer medicine centres have only limited engagement with clinical radiology. Clinical radiologists need to be more aware of how imaging is used to support research which can differ significantly from current clinical imaging (e.g. research is more quantitative.) It would be good if the ECMC imaging meetings coincided with UKRC for instance."

"Development of PET tracers and closer collaboration between centres as is being driven by the PET Research Network."

"One suggestion would be to set-up a faculty or network of medical device translational clinical scientists and clinicians with experience in the areas needed to get trials of devices up and running. This faculty would be a first port of call for academia and industry. No need for a centralised quango, just a grouping of like minded clinicians and clinical scientists with commercial, regulatory and trials experience. They would form a critical part of a pipeline leading from academia to the clinic for the emerging optical technologies."

Building capacity and skills:

"This will take time, patience and sustained focus/direction. Ultimately, this could be achieved by making joint training programmes, in which new talent is not prejudiced by existing disciplinary divides at an early stage in their career. This would also mean a teaching faculty that would have to effectively communicate and be proactive with a bigger picture in mind."

"Multi-centre studies with components of training, sharing best practice as well as quality assurance and data sharing. Encourage funding of studies similar to some existing BIDD projects but with clearer training component."

"Support networks for those who are unsure how to proceed. An open invitation from a SoR or CoR research rep to join an on-line forum and share successes and problems might be useful. Updates could be posted in Synergy or similar."

"Image analysis training. This could be achieved through integration with the Higher Specialist Scientific Training Programme being designed by the DH in conjunction with the Royal Colleges and Professional Bodies. This would offer a route to develop core skills in the workplace to support clinical trials. DH is also promoting an academic pathway for Clinical Scientists to support this type of activity as outlined previously."

Multicentre imaging trials:

"Greater coordination = larger sample sizes = more statistical power to detect a treatment effect. This could be achieved by funding such "networks" and providing incentive for researchers to use them."

"Research trials of sufficient power to answer specific clinical questions. make sure that there is sufficient man power to run these trials and these are utilised also as a training opportunities for your researchers (scientists or clinicians involved in MD / PhD)."

"Larger centrally coordinated studies have greater power and less chance of replicating studies performed elsewhere."

"We need to find a way to get collaborative centres to image patients without each centre having a full-time researcher. I favour a model in which major centres would be able to bid to run imaging trials, and if successful they would get a staff member to run the trial. They would also be able to submit scans to other trials (managed from other centres) for which they would be paid ad hoc. We also need a structure to channel novel imaging methods into clinical trials that will generate statistically robust data."

Specific topics:

"Coordination is particularly important for rarer cancers, which allows collection of larger cohorts."

"Modelling of normal and variant – there is a lack of basic knowledge, particularly with CT and MR, as to what is the normal range of appearance. Yet this information is actually there on the PACs system is we were to look for it. It would form a backbone for clinical decision making and future research. Funding in this area is not currently adequate and should be in the same level as genomic funding."

"All phases of therapeutic development would benefit from a realisation that the primary endpoint of most studies comes from imaging – the basic tenets of which have not changed significantly in 20 years (RECIST simply being a refinement of existing guidelines). Coordinating imaging to improve objective trial endpoints by development and validation would potentially reduce the number of patients required in clinical trials and speed up the process."

"PET tracer development and joint purchasing: identification of one tracer that should be prioritised for this and provision of substantial funding to achieve it. To demonstrate outcomes that can be achieved with such an approach, anticipated to be rapid evaluation of a new tracer followed by widespread adoption, if appropriate."

Glossary

Imaging terms

BOLD	Blood oxygenation level-dependent
CT	Computerised tomograpy
DEXA	Dual-energy X-ray absorptiometry
DW-MRI	Diffusion-weighted magnetic resonance imaging
IGRT	Image-guided radiotherapy
MR	Magnetic resonance
MRI	Magnetic resonance imaging
MRS	Magnetic resonance spectroscopy
PACS	Picture Archiving and Communications System
PET	Positron emission tomography
RECIST	Response Evaluation Criteria In Solid Tumors
QA	Quality assurance
QC	Quality control
SPECT	Single photon emission computed tomography
STARD	STAndards for the Reporting of Diagnostic accuracy
TEP	Two-photon extracellular polar-tracer
US	Ultrasound

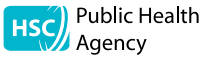
Other

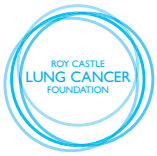
CI	Chief investigator
CRF	Clinical research facility
CTU	Clinical trials unit
HEI	Higher education institute
IT	Information technology
PI	Principal investigator
R&D	Research and development

Organisations

BBSRC	Biotechnology & Biological Sciences Research Council
BIDD	Biomarkers and Imaging Discovery and Development (a recently disbanded Cancer Research UK funding stream)
BIRN	Biomedical Informatics Research Network
BNMS	British Nuclear Medicine Society
CIC	Cancer Imaging Centre (referring to the CR-UK/EPSRC-funded centres)
CLRN	Comprehensive Local Research Network
CR-UK	Cancer Research UK
DH	Department of Health
ECMC	Experimental Cancer Medicine Centre
EORTC	European Organisation for Research and Treatment of Cancer
EPSRC	Engineering and Physical Sciences Research Council
HTA	NIHR Health Technology Assessment programme
IPEM	Institute of Physics and Engineering in Medicine
MRC	Medical Research Council
NCRI	National Cancer Research Institute
NCRN	NIHR Cancer Research Network
NHS	National Health Service
NICE	National Institute for Health and Clinical Excellence
NIHR	National Institute for Health Research
RCR	Royal College of Radiologists
SCoR	Society and College of Radiographers

NCRI Partners





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