

Public reporting of outcomes in radiation oncology: The National Prostate Cancer Audit

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Abstract:

The public reporting of patient outcomes is crucial for quality improvement and informing patient choice. However, outcome reporting in radiotherapy, despite being a major component of cancer control and cure, remains extremely limited internationally. Public reporting encounters a number of challenges: difficulties in defining meaningful measures of treatment quality, limitations in data infrastructure, and fragmented health insurance schemes. The National Prostate Cancer Audit (NPCA) carried out in the England and Wales National Health Service (NHS), demonstrates that it is feasible to develop outcome indicators for radiotherapy treatment including those using patient reported outcomes (PROs). This national programme provides a transparent mechanism for comparing performance of all NHS providers, with results accessible to patients, providers and policymakers. Using the NPCA as a case study we discuss the development of a radiotherapy outcomes reporting programme, its impact and future potential, and the challenges and opportunities to develop this approach across other tumour types and in different health systems.

Background

The National Prostate Cancer Audit was initiated in April 2013 and set out to assess the structure, organisation and availability of prostate cancer services in England and Wales as well as to prospectively collect information on processes and outcomes of care for all men newly diagnosed with prostate cancer.¹ In February 2019, as part of this remit, the NPCA established the first national radiotherapy outcomes reporting programme, which included all men receiving radical radiotherapy for prostate cancer in the National Health Service (NHS) in England and Wales.² The results are published in the public domain in order to support greater transparency and quality improvement. This article discusses the background to public reporting of patient outcomes, the development of the NPCA's reporting programme for prostate cancer, its impact, and the challenges and opportunities for broadening radiotherapy outcome reporting to other tumour types and health systems.

Within cancer care there continues to be a focus on access to advanced and novel technologies with the aim of improving functional and survival outcomes for patients.³ However, it is widely acknowledged that irrespective of the perceived benefits of the technology, significant variations in the quality of care may exist. Reasons include differences in the skill of the physicians or teams that deliver the treatment, the clinical care pathway adopted and the infrastructure of the hospital with respect to facilities, human resources, and organisational structure.⁴

As a result, many health systems publish indicators of the performance of hospitals and health care professionals in the public domain to provide transparency on differences in the quality of care that exist within that health system. This enables comparisons of performance over time, between hospitals and professionals and against pre-existing standards of care that have been defined from clinical trials and national consensus statements by professional bodies.^{5,6} It also provides a mechanism for informing value-based health care initiatives, which seek to define efficient and cost-effective practices of care.⁷

Currently four broad types of measures predominate⁸: outcomes measures (e.g. complications, post-treatment function, quality of life, cancer-specific and overall survival); process measures (e.g. waiting times, procedure volume, length of stay); structural measures (e.g. availability of specific technologies or services); and measures of patient experience and satisfaction.

The anticipated benefits from public reporting of outcomes include enhanced transparency and accountability for hospitals which in turn enables patients to make informed choices about where they receive care.⁹ They should also support quality improvement either through market mechanisms¹⁰ (Quality competition) or regulation by reducing information asymmetry regarding care quality and safety.^{11,12}

Radiotherapy

Radiation oncology, is one of the major modalities of cancer control and cure, yet there is little or no evidence available that advances in practice are translating into better patient outcomes (survival, toxicity or function) across health care providers in the real world. Globally, there has been very limited public reporting of outcomes either of efficacy (e.g. local control, survival) or toxicity following radiotherapy and where they are available they almost exclusively consider structural or process indicators.^{13,14}

Benchmarking activities against process measures e.g. adherence to dosimetric criteria, use of image guided radiotherapy (IGRT) and treatment margins have been undertaken using surveys and national quality improvement initiatives (e.g. Quality Research in Radiation Oncology).¹⁵⁻³² However, these measures remain quite limited in defining the quality of care received.³³ This is due to a lack of a clearly defined link between process and outcome, as well as uncertainty regarding the magnitude of effect on functional and oncological outcomes from non-adherence.^{14,16}

In the United States, only the 11 cancer centres that are exempt from the prospective payment system are required to report performance indicators as part of the PPS-Exempt Cancer Hospital Quality Reporting Program (PCHQR)³⁴. This is only a small fraction of the 3500 hospitals providing cancer services in the United States and none of these performance indicators relate to treatment outcomes (<https://www.medicare.gov/hospitalcompare/cancer-measures-data.html>). Groups in the Netherlands (<https://www.iknl.nl/over-iknl/about-iknl>; <https://dica.nl/>) and Canada (<https://www.csqi.on.ca>; <https://www.systemperformance.ca>) are developing outcome indicators but these initiatives remain a work in progress.⁸ The UK is the first country to introduce a national public outcomes reporting programme for radiotherapy.

The NHS Cancer outcomes reporting programme

In 2013, NHS England introduced the Clinical Outcomes Publication programme. This initiative set out to publish quality measures at the level of the individual consultant, team or hospital.³⁵ The outcomes are expected to be provided by pre-existing national clinical audits as part of the National Clinical Audit and Patient Outcomes Programme. The advantage of this in the context of the NHS is that it is a publicly-funded health care system covering 95% of patients receiving cancer treatment.

There are currently five national cancer audits covering patients treated in the NHS in England and Wales^{2,36-39} – breast, bowel, oesophageal/gastric, prostate, and lung cancers. The National Prostate Cancer Audit (NPCA)² is unique in that it is the first of these audits to develop and measure treatment-outcome indicators for radical radiotherapy.

The National Prostate Cancer audit radiotherapy outcomes reporting programme

Since 2019 the NPCA publishes risk-adjusted treatment toxicities and functional outcomes for each radiotherapy centre in England and Wales (n=55). One of the advantages of the NPCA approach is the use of pre-existing administrative datasets and hospital IT infrastructure, which minimises the burden of data collection on clinicians. This includes four linked datasets (Hospital Episode Statistics (HES), cancer registry, the radiotherapy data set (RTDS), and the systemic anticancer treatment (SACT)), which provide information on patient and tumour characteristics, episodes of care and detailed information on radiotherapy treatment. The advantage of this approach is that it provides a standardised and validated mechanism for data capture with high levels of case ascertainment. This obviates increasing concerns regarding under-reporting of adverse events especially where care is fragmented across several hospitals, (e.g. centralised hub and spoke models). The second advantage is that it reduces the likelihood of misclassification bias by using a standardised coding approach, for grading toxicity which, is not dependent on individual clinician reporting. This improves specificity for the recording of outcomes.

Another unique component of the NPCA is the survey collecting patient-reported outcome and experience measures on a large scale. These include the Expanded Prostate Cancer Index Composite short-form (EPIC-26), a validated instrument comprising 26 items to measure patient function and bother in five domains, and the EuroQoL EQ-5D-5L, an instrument to measure health-related quality of life. The survey was sent out approximately 12 months after receipt of radical radiotherapy and has been also used to compare outcomes across different treatment practices.⁴⁰ The first survey, published in 2018, had a 73% response rate (25,490 out of 35,162 questionnaires sent) and a second round of data collection will be published in 2020. Of the EPIC-26's five main domains, two are selected routinely as part of the outcomes reporting programme.

The reporting programme is designed to report outcomes, in order to identify both outlying performance and good practice as opposed to ranking individual centres. By using funnel plots to compare individual provider results with the national average, we identify 'potential negative outliers' whose performance is outside acceptable limits corresponding to three standard deviations (further from the national average than would usually occur by chance alone).

<https://www.npca.org.uk/resources/npca-outlier-policy/>.⁴¹

If outliers are identified, the hospital's lead clinician, medical director and chief executive are contacted and given the opportunity to review their own data and provide a formal response including a local quality improvement plan that is published alongside the results for their hospital.² Patients, providers and commissioners are able to access the results for each NHS hospital providing

prostate cancer treatment services via the provider reporting portal on the audit website (<https://www.npca.org.uk/provider-results/>). A Quality Improvement action plan template is also provided including the key recommendations from the report and suggested actions for providers. <https://www.npca.org.uk/reports/npca-annual-report-2018/>.

Development of the radiotherapy performance indicators

The first indicator assesses the percentage of men at each radiotherapy centre who experienced at least one gastro-intestinal (GI) complication within 2 years of their radiotherapy (Figure 1), using procedure and diagnostic codes derived from patient-level linked administrative hospital data. A toxicity event requires evidence of both a diagnostic endoscopic procedure (e.g. colonoscopy or sigmoidoscopy) in addition to a diagnostic code consistent with radiation toxicity equivalent to Grade 2 toxicity or above according to the National Cancer Institute Common Toxicity Criteria for Adverse Events (CTCAE).^{42,43} These indicators have been validated and used to compare the effectiveness of different treatment modalities and processes of care in prostate cancer radiotherapy.⁴³⁻⁴⁵

For the hospital-level reporting programme, these toxicity indicators are adjusted for patient factors: age, cancer stage, comorbidities and socioeconomic status. However, they are not adjusted for treatment related factors (e.g. hypofractionation, pelvic lymph node treatment) because adjustment for differences in radiotherapy practice may inappropriately mask variation in outcomes between centres. Of note all NHS hospitals are delivering IMRT routinely and the audit does not report outcomes for patients receiving a brachytherapy boost or prostate bed radiotherapy.

The second and third indicators report the mean bowel function and sexual function respectively for patients treated at each radiotherapy centre. The results are based on the national survey collection of patient-reported outcome and experience measures (PROMs/PREMs) (Figures 2 and 3). The sexual function domain asks questions related to the quality and frequency of erections. The bowel function domain assesses bowel frequency, urgency, bleeding and pain. These patient-reported outcome indicators are then linked with the administrative datasets described above to enable relevant risk-adjustment prior to reporting.

Outcome reporting – the experience to date

The outcome reporting programme demonstrated considerable variation in toxicity across radiotherapy centres in the English and Welsh NHS. The overall rate of toxicity of Grade 2 or above is in the region of 10% at 2 years across all centres, but this varies by hospital ranging from 2% to 23% (Figure 1).

In the first year of the programme, two hospital ‘alarm’ outliers (whose rates of GI toxicity was more than three standard deviations from the national average) were identified as part of this process. Centres (both outliers and non-outliers) were able to request the audit data and review their outcomes and processes of care. This included case note review, analysis of dosimetry and radiotherapy contours, patient recall for assessment, and correspondence with primary care practitioners. These internal review processes validated the rates of toxicity reported through the audit. Only a very small number of patients had presented incidentally via the screening programme and the majority of referrals were for rectal bleeding. Formal responses from outliers are recorded in the audit reports.²

The second and third indicators, which included centre-level EPIC-26 bowel and sexual function scores, also identified negative outliers (Figures 2 and 3). Despite different methods of determining GI adverse events, a correlation was demonstrated between negative outliers for GI toxicity on the basis of routine clinical data (first indicator) and GI dysfunction (second indicator) reported by patients.

Three centres were identified as positive outliers because their results were below the lower 99.8% funnel limit for GI toxicity events (Figure 1). Of these three centres, one was also a positive outlier for bowel and sexual function scores from the patient reported outcomes and was consistently seen as the “best performer” when compared to all radiotherapy centres treating prostate cancer patients.

Will outcome reporting improve treatment quality?

The radiotherapy outcomes programme reported for the first time in 2019 and it is therefore too early to assess its impact on improvements in patient outcome: this will be tracked overtime by the NPCA. However, a number of initiatives have been set up in response to this programme.

On a national level, an annual quality improvement workshop for all NHS radiotherapy treatment providers in England and Wales has been initiated. Here, radiotherapy centres have the opportunity to reflect on their own results, report findings from internal audits including correlating their outcomes with individual patient dosimetry data, as well as to learn from other centres. **Box 1** highlights factors identified from analysis of negative and positive outliers who provided insights into their practice and processes of care. In addition, examples of local quality improvement initiatives implemented since commencement of the outcomes programme are outlined in **Box 2**.

Beyond prostate cancer, the impact of public reporting of hospital or clinician specific outcomes on the quality of patient care remains inconsistent at best.^{49,50} A study undertaken by the National Bowel Cancer Audit,⁵¹ found that the introduction of outcome reporting coincided with a reduction in 90-day

post-operative mortality from 2.8% to 2.1%, which exceeded the existing downward trend. Importantly, no risk-averse behaviour or gaming of data was observed.

The mechanism by which improvements in outcome are achieved is unclear. In the wider literature, three pathways have been postulated. The “change” pathway hypothesises that public reporting and identifying low accomplishment provides a strong incentive for clinicians and providers to improve by appealing to their professionalism.⁵² On the other hand, the “selection” pathway puts patients at the heart of quality improvement by enabling them to choose better performing hospitals, which in turn motivates providers to improve quality to attract more patients and preserve or gain market share.^{53,54} A third mechanism, “reputational loss,” appeals to the clinicians’ sense of their awareness of their standing among their colleagues. It has been suggested that this mechanism is a potential driver of quality improvement, particularly in poor-performing centres.⁵⁵

Will outcome reporting influence patient behaviour?

The impact of outcome reporting on patient behaviour and patient selection of hospitals is a poorly researched area within cancer care.⁵⁶ In other medical disciplines and health systems there is some evidence that patients move to seemingly better performing centres following publication of outcomes,^{57,58} but the results depend on the complexity of individual health systems and the nature and severity of the involved health conditions.

With respect to prostate cancer, recent studies have demonstrated that prior to outcome reporting, 1 in 3 patients undergoing prostate cancer surgery and 1 in 5 receiving radical radiotherapy travel to a centre other than their nearest for treatment (termed patient mobility) in the English NHS.⁵⁹⁻⁶² Nearly all patients expressed an interest in having access to comparative outcome indicators to inform their choices.⁶³ However, in their absence, factors such as the reputation of hospitals and individual clinicians, the availability of advanced technologies, and the experiences of other patients have been identified as most relevant.^{56,60,61}

It is important for the NPCA to avoid a common pitfall of public reporting, namely poor consumer or patient awareness of these indicators.⁵ The NPCA has sought to address this by engaging directly with patients and the public through its patient and public involvement (PPI) forum as well as its NHS clinical reference group which includes representation from national prostate cancer charities and support groups. These groups have been involved in the development of the clinical outcomes programme and through continued engagement with prostate cancer charities and support groups - who in turn are integrating this resource into their own information channels; it is expected that this information will inform decision-making. Empirically, we will assess this by analysing changes in patterns of patient mobility in response to outcome reporting using established methodologies.⁶¹ From the clinician

perspective we expect this centre-level information to help doctors and other health-care workers to counsel patients more effectively and transparently regarding toxicity and functional outcomes following radical treatment.

Outcome reporting – Challenges and opportunities

Infrastructure and political commitment

The NPCA has demonstrated that it is feasible to develop outcome indicators for radiotherapy treatment and thereby produce a transparent mechanism for comparing the performance of providers.^{64,65} However, there are a number of challenges to creating a similar outcome reporting programme in other health systems.¹¹ The differentiation of health care provision across private and public sectors makes the development of public reports that encompass all health-care provision a significant challenge.³³ In addition, for many reporting programmes participation is optional and there is little uniformity across provider organisations in terms of the content of public reports and the statistical and risk-adjustment methods.^{66,67} Attempts to create such centralised registries and national performance assessment projects in other countries have failed due to a lack of incentive amongst physicians and providers as well as the costs associated with collating data across heavily fragmented public and private systems.⁶⁸ Other challenges, where registries exist, include poor completion of radiotherapy datasets (providing information on target volumes, dose, fractionation and site of treatment).¹⁶

In the NHS, political commitment has ensured that the necessary financial resource has been made available to set up national cancer audits in England and Wales as part of the Clinical Outcomes Publication Programme. Methodological and clinical teams have been established who in turn have defined, developed and implemented performance indicators reflecting outcomes of cancer care at a national level. The cost itself for developing this programme, equates to approximately 1.7 million GBP over 5 years which is 0.002 % of the median estimated cost for developing a new therapeutic agent (710 million GBP)⁶⁹ and is significant value for money given the information it provides around variation in access and outcomes of cancer treatment.

Gaming and inappropriate use of data

The risk of “gaming”, where data may be manipulated to increase patients’ predicted risk or to make patients ineligible for public reporting, is likely to be negligible in the NPCA reporting programme as this uses existing administrative patient-level datasets and national surveys of patients using validated PROMs tools. The GI toxicity indicator also avoids the need for subjective assessment, addressing concerns that clinicians might manipulate outcome data. In addition, clinicians and hospitals do not

select patients for the PROMS survey and they are blinded to the results. Instead, the survey is administered by an independent body, and sent to all patients treated at NHS hospitals. This also reduces the burden of data collection on hospitals. The high response rate (close to 75%) reflects the acceptance of patients for this process.

Risk averse behaviour or “cream skimming”, whereby lower risk patients are differentially selected by clinicians for a procedure does remain a possibility with any reporting programme, but is minimised within the NPCA through hospital, rather than clinician level reporting, and the use of routine data for outcome assessment. To mitigate the impact of risk averse behaviour, the reporting system does adjust for age, stage, comorbidity and socioeconomic status. Other baseline factors may also be considered in the future.

Indicator development - Efficacy and toxicity

Developing outcome measures in cancer care is challenging as it is a complex discipline incorporating a diverse set of interventions delivered with radical or palliative intent, encapsulating modalities such as surgery, radiotherapy and chemotherapy either on their own or in combination.⁷⁰ Generic outcome measures will rarely be applicable and will need to be adapted depending on the type of procedure and the cancer in question.

For radiotherapy, the balance between efficacy e.g. local control and toxicity is essential to understanding outcome. However, some limitations exist to achieving this. For prostate cancer, it may be many years before it is appropriate to measure survival, during which time clinical practice can change considerably. As a result, treatment-related toxicity and patient-reported functional outcomes are of particular importance as they are available sooner and provide a meaningful measure of treatment effectiveness. This is particularly important in a specialty where rapid technological change and iterations in practices occur frequently.^{44,45}

As the radiotherapy outcomes programme extends towards other tumour types, measures of both toxicity and efficacy may be more readily achievable e.g. in oesophageal cancer. However, this does require substantial methodological work as one of the limitations of these datasets is that they do not routinely record the date of key measures such as disease recurrence. Work is currently being undertaken across the audits to develop such measures e.g. disease free survival, and for prostate cancer specifically, this has involved the development of an indicator for skeletal related events.⁷¹ As reporting extends to other combination therapies, e.g. radiation followed by surgery for rectal cancer, a different profile of indicators may need to be considered which in addition to local control may need

to also include post-operative outcomes such as complication, readmission and permanent stoma rates.

Value based health care and health care markets

Currently there are significant differences in radiotherapy practice delivered nationally and internationally, both in terms of modalities and pathways of care (e.g. stereotactic versus intensity modulated radiotherapy/dose fractionation/IGRT) resulting in significant variation in costs, without a clear understanding of the impact of outcomes in the real world.⁷²

A major finding from the reporting programme is that the differences between the best and worst performers was not due to variation in access to innovation such as proton beam therapy (no NHS centres provide this treatment for prostate cancer) or rectal spacer techniques (only one NHS centre uses this routinely). Instead, the national benchmarking exercise, described differences in quality assurance processes and routine practices (Box 1), which can be readily adopted immediately by all centres at negligible cost.

Outcome reporting through greater transparency around best practices can therefore help to overcome this “information asymmetry” and reliance on proxies of healthcare quality (e.g. technology adoption, physician reputation), rationally guiding investments by purchasers of health services and limiting perverse incentives for hospitals to adopt inefficient practices of care.⁷²

Cancer surgery provides a relevant example of the potential negative impact of the absence of robust outcome data to inform choice. In the UK, patient choice and provider competition policies have influenced the widespread adoption of high-cost robotic technology for prostate surgery despite limited evidence that it improves -cancer-cure or functional outcomes.^{62,73} Information on treatment outcomes is therefore imperative to support patient choice, and the effectiveness of health care markets.

In addition, in mixed public and private health care models the transparency and accountability that outcomes reporting brings within the public sector can form the basis for encouraging private health care providers to report their outcomes as part of a unified approach to outcome transparency and accountability⁷⁴. This can be implemented through direct regulation or through patient’s voices, as consumers of health care demand information to guide their choices.

Price transparency is another important issue and the quality outcomes reported can be linked with detailed pricing information. In systems such as the US, this approach could provide the necessary incentive to lower spending and improve care within managed health care markets.^{75,76,77} Conversely, in fixed priced markets such as the NHS, outcome reporting can also influence decisions of purchasers

or commissioners of health services with the aim of controlling costs or to obtain the best possible outcomes within a limited budget, particularly where reward or penalty schemes exist.^{78,79} More broadly within the radiotherapy arena, understanding these trade-offs would be greatly facilitated by standardising the methods for costing radiotherapy practices, which remain highly variable.⁸⁰ In this regard, the Time Driven-Activity Based Costing model developed by the Health Economics in Radiation Oncology project, provides a framework for assessing the clinical and economic benefit of new radiation therapy technologies and supporting value based health care initiatives.^{7,81}

Conclusion

The public reporting of patient outcomes at the individual hospital and clinician-level has been continuing apace since its initial introduction in the late 1980s. One of its major benefits is the enhanced transparency and accountability for hospitals regarding the quality of healthcare they deliver. In turn, these outcome indicators can enable patient choice, benchmark best practice and support quality improvement initiatives. This lack of public reporting in radiotherapy is largely due to limitations in data infrastructure, and fragmented health insurance schemes. The NHS in England and Wales has led the way for radiotherapy reporting since 2019, demonstrating the feasibility of collating and publishing outcomes at the hospital-level. The results are accessible to patients, the public and clinicians and are designed to identify outlying hospital performance and enable hospitals to benchmark their performance relative to the national average across all hospitals. The impact of the reporting programme needs further assessment and further work is ongoing to develop and refine new outcome indicators for prostate cancer and other tumour types.

Search strategy and selection criteria:

References for this review were identified through searches of PubMed with the search terms “Radiotherapy” AND (Patient Outcomes OR Clinical Outcomes”) AND (hospital OR provider) AND (“public reporting OR performance measurement OR rankings) from 01/01/1990 until 01/05/2020. Articles were also identified through searches of the authors’ own files. Only papers published in English were reviewed. The final reference list was generated on the basis of originality and relevance to the broad scope of this review. The search did not identify any evidence for other public radiotherapy outcomes reporting initiatives. Studies focused on local quality improvement initiatives within radiation oncology, using process measures that were not publicly reported.

Author Contributions

AA, and JvdM conceived and designed the policy review. AA, undertook the literature search. MP provided manuscript figures. AA, JN, JvdM and HP wrote the first draft of the paper. AA, JN, MP, AS, NC, AZ, HP, JvdM involved in reviewing and editing drafts of paper and approving final manuscript.

Conflict of Interest Statement

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REFERENCES

1. Royal College of Surgeons of England. National Prostate Cancer Audit - First Year Annual Report - Organisation of Services and Analysis of Existing Clinical Data. 2014.
2. Royal College of Surgeons of England. National Prostate Cancer Audit - Annual Report 2018. . 2018.
3. Ryll B. No other interest can take precedence — a patient’s perspective on oncology drug development. *Nature Reviews Clinical Oncology* 2019.
4. Donabedian A. The quality of care. How can it be assessed? *Jama* 1988; **260**(12): 1743-8.
5. Hussey PS, Luft HS, McNamara P. Public Reporting of Provider Performance at a Crossroads in the United States: Summary of Current Barriers and Recommendations on How to Move Forward. *Medical Care Research and Review* 2014; **71**(5_suppl): 5S-16S.
6. Marshall M, McLoughlin V. How do patients use information on health providers? *BMJ* 2010; **341**.
7. Lievens Y, Audisio R, Banks I, et al. Towards an evidence-informed value scale for surgical and radiation oncology: a multi-stakeholder perspective. *The Lancet Oncology* 2019; **20**(2): e112-e23.
8. Rechel B, McKee M, Haas M, et al. Public reporting on quality, waiting times and patient experience in 11 high-income countries. *Health Policy* 2016; **120**(4): 377-83.
9. Marshall MN, Shekelle PG, Leatherman S, Brook RH. The public release of performance data: what do we expect to gain? A review of the evidence. *Jama* 2000; **283**(14): 1866-74.
10. Aggarwal AK, Sujenthiran A, Lewis D, et al. Impact of patient choice and hospital competition on patient outcomes after prostate cancer surgery: A national population-based study. *Cancer* 2019.
11. Spinks TE, Walters R, Feeley TW, et al. Improving cancer care through public reporting of meaningful quality measures. *Health Aff (Millwood)* 2011; **30**(4): 664-72.
12. Vallance AE, vanderMeulen J, Kuryba A, et al. Impact of hepatobiliary service centralization on treatment and outcomes in patients with colorectal cancer and liver metastases. *Br J Surg* 2017; **104**(7): 918-25.
13. Thaker NG, Sturdevant L, Jhingran A, et al. Assessing the Quality of a Radiation Oncology Case-Based, Peer-Review Program in an Integrated Academic and Community Cancer Center Network. *J Oncol Pract* 2016; **12**(4): e476-86.

14. Danielson B, Brundage M, Pearcey R, et al. Development of indicators of the quality of radiotherapy for localized prostate cancer. *Radiother Oncol* 2011; **99**(1): 29-36.
15. Siddiqui F, Liu AK, Watkins-Bruner D, Movsas B. Patient-reported outcomes and survivorship in radiation oncology: overcoming the cons. *Journal of clinical oncology : official journal of the American Society of Clinical Oncology* 2014; **32**(26): 2920-7.
16. Albert JM, Das P. Quality indicators in radiation oncology. *International Journal of Radiation Oncology* Biology* Physics* 2013; **85**(4): 904-11.
17. Lopez Torrecilla J, Marin IBS, Ruiz-Alonso A, et al. Quality indicators in radiation oncology: proposal of the Spanish Society of Radiation Oncology (SEOR) for a continuous improvement of the quality of care in oncology. *Clin Transl Oncol* 2019; **21**(4): 519-33.
18. Vaandering A, Jornet N, Scalliet P, Coffey M, Lievens Y. Doing the right thing: Quality in radiotherapy, a European perspective. *Radiother Oncol* 2018; **127**(2): 161-3.
19. Wilson JF, Owen J. Quality Research in Radiation Oncology: A Self-Improvement Initiative 30 Years Ahead of Its Time? *Journal of the American College of Radiology* 2005; **2**(12): 1001-7.
20. Best L, de Metz C, Olivotto IA, et al. Radiation therapy quality indicators for invasive breast cancer. *Radiother Oncol* 2017; **123**(2): 288-93.
21. Khare SR, Aprikian A, Black P, et al. Quality indicators in the management of bladder cancer: A modified Delphi study. *Urol Oncol* 2017; **35**(6): 328-34.
22. Gabriele P, Maggio A, Garibaldi E, et al. Quality indicators in the intensity modulated/image-guided radiotherapy era. *Crit Rev Oncol Hematol* 2016; **108**: 52-61.
23. Bao H, Yang F, Wang X, et al. Developing a set of quality indicators for breast cancer care in China. *Int J Qual Health Care* 2015; **27**(4): 291-6.
24. Donaldson H, Cao J, French J, et al. Quality standards in radiation medicine. *Practical radiation oncology* 2014; **4**(4): 208-14.
25. Zelefsky MJ, Lee WR, Zietman A, et al. Evaluation of Adherence to Quality Measures for Prostate Cancer Radiotherapy in the United States: Results from the Quality Research in Radiation Oncology (QRRO) Survey. *Practical radiation oncology* 2013; **3**(1): 2-8.
26. Komaki R, Khalid N, Langer CJ, et al. Penetration of recommended procedures for lung cancer staging and management in the United States over 10 years: a quality research in radiation oncology survey. *Int J Radiat Oncol Biol Phys* 2013; **85**(4): 1082-9.
27. Goodman KA, Khalid N, Kachnic LA, et al. Quality Research in Radiation Oncology analysis of clinical performance measures in the management of gastric cancer. *Int J Radiat Oncol Biol Phys* 2013; **85**(2): 355-62.
28. Brucker SY, Wallwiener M, Kreienberg R, et al. Optimizing the quality of breast cancer care at certified german breast centers: a benchmarking analysis for 2003-2009 with a particular focus on the interdisciplinary specialty of radiation oncology. *Strahlenther Onkol* 2011; **187**(2): 89-99.
29. Owen JB, White JR, Zelefsky MJ, Wilson JF. Using QRRO survey data to assess compliance with quality indicators for breast and prostate cancer. *J Am Coll Radiol* 2009; **6**(6): 442-7.
30. Bekelman JE, Zelefsky MJ, Jang TL, Basch EM, Schrag D. Variation in adherence to external beam radiotherapy quality measures among elderly men with localized prostate cancer. *Int J Radiat Oncol Biol Phys* 2007; **69**(5): 1456-66.
31. Crozier C, Erickson-Wittmann B, Movsas B, Owen J, Khalid N, Wilson JF. Shifting the focus to practice quality improvement in radiation oncology. *J Healthc Qual* 2011; **33**(5): 49-57.
32. Khalid N, Movsas B, Owen JB, Crozier CL, Wilson JF. QRRO: Estimating National Benchmarks for Quality Indicators for Non-small Cell Lung Cancer (NSCLC). *International Journal of Radiation Oncology • Biology • Physics* 2009; **75**(3): S444-S5.
33. Goldberg P, Conti RM. Problems with public reporting of cancer quality outcomes data. *J Oncol Pract* 2014; **10**(3): 215-8.
34. Merkow RP, Yang AD, Pavey E, et al. Comparison of Hospitals Affiliated With PPS-Exempt Cancer Centers, Other Hospitals Affiliated With NCI-Designated Cancer Centers, and Other Hospitals That Provide Cancer Care. *JAMA Intern Med* 2019; **179**(8):1043-1051.

35. Health Quality Improvement Partnership. Clinical Outcomes Publication: Technical Manual, 2016. <https://www.hqip.org.uk/national-programmes/>
36. Royal College of Surgeons of England. National Bowel Cancer Audit - Annual report 2018, 2018. <https://www.nboca.org.uk/content/uploads/2018/12/NBOCA-annual-report2018.pdf>
37. Royal College of Surgeons of England. National Oesophago-Gastric Cancer Audit - Annual report 2018, 2018. <https://www.nogca.org.uk/content/uploads/2019/04/NOGCA-2018-Annual-Report-V2.pdf>
38. Royal College of Surgeons of England. National Audit of Breast Cancer in Older Patients - 2019 Annual Report. 2019. <https://www.nabcop.org.uk/reports/nabcop-2019-annual-report/>
39. Royal College of Surgeons of Physicians. National Lung Cancer Audit Annual report 2018. 2019. <https://www.rcplondon.ac.uk/projects/outputs/nlca-annual-report-2018>
40. Nossiter J, Sujenthiran A, Cowling TE, et al. Patient-Reported Functional Outcomes After Hypofractionated or Conventionally Fractionated Radiation for Prostate Cancer: A National Cohort Study in England. *Journal of Clinical Oncology* 2020; **38**(7): 744-52.
41. Royal College of Surgeons of England. National Prostate Cancer Audit: Outlier Policy 2018, 2019. https://www.npca.org.uk/content/uploads/2018/10/NPCA-Outlier-Policy_Annual-Report-2018_V2.4_261018.pdf
42. National Institutes of Health NCI. Common Terminology Criteria for Adverse Events (CTCAE). http://www.eortc.be/services/doc/ctc/CTCAE_4.03_2010-06-14_QuickReference_5x7.pdf (accessed January 8 2019).
43. Sujenthiran A, Nossiter J, Charman SC, et al. National population-based study comparing treatment-related toxicity in men who received Intensity-Modulated versus 3D-Conformal Radical Radiotherapy for prostate cancer. *International Journal of Radiation Oncology*Biophysics*Physics* 2017.
44. Parry MG, Sujenthiran A, Cowling TE, et al. Treatment-Related Toxicity Using Prostate-Only Versus Prostate and Pelvic Lymph Node Intensity-Modulated Radiation Therapy: A National Population-Based Study. *Journal of clinical oncology : official journal of the American Society of Clinical Oncology* 2019: Jco1802237.
45. Sujenthiran A, Parry M, Nossiter J, et al. Comparison of Treatment-Related Toxicity With Hypofractionated or Conventionally Fractionated Radiation Therapy for Prostate Cancer: A National Population-Based Study. *Clin Oncol (R Coll Radiol)* 2020; **32**(8): 501-8.
46. Dearnaley D, Syndikus I, Mossop H, et al. Conventional versus hypofractionated high-dose intensity-modulated radiotherapy for prostate cancer: 5-year outcomes of the randomised, non-inferiority, phase 3 CHHiP trial. *The Lancet Oncology* 2016; **17**(8): 1047-60.
47. Wilkins A, Naismith O, Brand D, et al. Derivation of Dose/Volume Constraints for the Anorectum from Clinician- and Patient-Reported Outcomes in the CHHiP Trial of Radiation Therapy Fractionation. *International Journal of Radiation Oncology • Biology • Physics* 2020; **106**(5): 928-38.
48. Miller LE, Efstathiou JA, Bhattacharyya SK, Payne HA, Woodward E, Pinkawa M. Association of the Placement of a Perirectal Hydrogel Spacer With the Clinical Outcomes of Men Receiving Radiotherapy for Prostate Cancer: A Systematic Review and Meta-analysis. *JAMA Network Open* 2020; **3**(6): e208221-e.
49. Fung CH, Lim YW, Mattke S, Damberg C, Shekelle PG. Systematic review: the evidence that publishing patient care performance data improves quality of care. *Ann Intern Med* 2008; **148**(2): 111-23.
50. Campanella P, Vukovic V, Parente P, Sulejmani A, Ricciardi W, Specchia ML. The impact of Public Reporting on clinical outcomes: a systematic review and meta-analysis. *BMC Health Serv Res* 2016; **16**: 296.
51. Vallance AE, Fearnhead NS, Kuryba A, et al. Effect of public reporting of surgeons' outcomes on patient selection, "gaming," and mortality in colorectal cancer surgery in England: population based cohort study. *BMJ* 2018; **361**: k1581.
52. Berwick DM, James B, Coye MJ. Connections between quality measurement and improvement. *Medical care* 2003; **41**(1): I-30-I-8.

53. Le Grand J. The other invisible hand: Delivering public services through choice and competition: Princeton University Press; 2009.
54. Aggarwal AK, Sujenthiran A, Lewis D, et al. Impact of patient choice and hospital competition on patient outcomes after prostate cancer surgery: A national population-based study. *Cancer* 2019; **125**(11): 1898-907.
55. Hibbard JH, Stockard J, Tusler M. Does publicizing hospital performance stimulate quality improvement efforts? *Health Aff (Millwood)* 2003; **22**(2): 84-94.
56. Aggarwal A, Lewis D, Mason M, Sullivan R, van der Meulen J. Patient Mobility for Elective Secondary Health Care Services in Response to Patient Choice Policies: A Systematic Review. *Medical Care Research and Review* 2016; **74**(4): 379-403.
57. Pope DG. Reacting to rankings: Evidence from "America's Best Hospitals". *Journal of Health Economics* 2009; **28**(6): 1154-65.
58. Gutacker N, Siciliani L, Moscelli G, Gravelle H. Choice of hospital: Which type of quality matters? *Journal of Health Economics* 2016; **50**: 230-46.
59. Aggarwal A, Bernays S, Payne H, van der Meulen J, Davis C. Hospital Choice in Cancer Care: A Qualitative Study. *Clin Oncol (R Coll Radiol)* 2018; **30**(7): e67-e73.
60. Aggarwal A, Lewis D, Charman SC, et al. Determinants of Patient Mobility for Prostate Cancer Surgery: A Population-based Study of Choice and Competition. *Eur Urol* 2018; **73**(6):822-825.
61. Aggarwal A, Lewis D, Sujenthiran A, et al. Hospital quality factors influencing the mobility of patients for radical prostate cancer radiotherapy: a national population based study. *International Journal of Radiation Oncology • Biology • Physics* 2017; **99**(5):1261-1270.
62. Aggarwal A, Lewis D, Mason M, Purushotham A, Sullivan R, van der Meulen J. Effect of patient choice and hospital competition on service configuration and technology adoption within cancer surgery: a national, population-based study. *The Lancet Oncology* 2017; **18**(11): 1445-53.
63. Chimonas S, Fortier E, Li DG, Lipitz-Snyderman A. Facts and Fears in Public Reporting: Patients' Information Needs and Priorities When Selecting a Hospital for Cancer Care. *Med Decis Making* 2019: 272989x19855050.
64. Health Quality Improvement Partnership (HQIP). National Clinical Audit and Patient Outcome Programme - Reporting. 2019. <https://www.hqip.org.uk/a-z-of-nca/#.X1EpoeeSmUI>
65. Geary RS, Knight HE, Carroll FE, et al. A step-wise approach to developing indicators to compare the performance of maternity units using hospital administrative data. *Bjog* 2018; **125**(7): 857-65.
66. Austin JM, Jha AK, Romano PS, et al. National hospital ratings systems share few common scores and may generate confusion instead of clarity. *Health Aff (Millwood)* 2015; **34**(3): 423-30.
67. Cassel CK, Conway PH, Delbanco SF, Jha AK, Saunders RS, Lee TH. Getting more performance from performance measurement. *The New England journal of medicine* 2014; **371**(23): 2145-7.
68. Palta JR, Efstathiou JA, Bekelman JE, et al. Developing a national radiation oncology registry: From acorns to oaks. *Practical radiation oncology* 2012; **2**(1): 10-7.
69. Wouters OJ, McKee M, Luyten J. Estimated Research and Development Investment Needed to Bring a New Medicine to Market, 2009-2018. *Jama* 2020; **323**(9): 844-53.
70. Albert JM, Das P. Quality assessment in oncology. *Int J Radiat Oncol Biol Phys* 2012; **83**(3): 773-81.
71. Parry MG, Cowling TE, Sujenthiran A, et al. Identifying skeletal-related events for prostate cancer patients in routinely collected hospital data. *Cancer epidemiology* 2019; **63**: 101628.
72. Lievens Y, Grau C, Aggarwal A. Value-based health care - what does it mean for radiotherapy? *Acta Oncol* 2019: 1-5.
73. Nossiter J, Sujenthiran A, Charman SC, et al. Robot-assisted radical prostatectomy vs laparoscopic and open retropubic radical prostatectomy: functional outcomes 18 months after diagnosis from a national cohort study in England. *British journal of cancer* 2018; **118**(4): 489-94.
74. Spencer K, Morris E. Collection of routine cancer data from private health-care providers. *The Lancet Oncology* 2019; **20**(9): 1202-4.

75. Gaynor M. Competition in Health Care Markets 2011. <https://www.nber.org/papers/w17208.pdf> (accessed Jan 18 2020).
76. Gaynor M, Ho K, Town RJ. The Industrial Organization of Health-Care Markets. *Journal of Economic Literature* 2015; **53**(2): 235-84.
77. Dor A, Koroukian S, Xu F, Stulberg J, Delaney C, Cooper G. Pricing of surgeries for colon cancer: patient severity and market factors. *Cancer* 2012; **118**(23): 5741-8.
78. James J. Public reporting on Quality and Costs. Health Affairs Health Policy Brief, March 8 2012. DOI 10.1377/hpb20120308.53696
79. Sinaiko AD, Eastman D, Rosenthal MB. How report cards on physicians, physician groups, and hospitals can have greater impact on consumer choices. *Health Aff (Millwood)* 2012; **31**(3): 602-11.
80. Defourny N, Dunscombe P, Perrier L, Grau C, Lievens Y. Cost evaluations of radiotherapy: What do we know? An ESTRO-HERO analysis. *Radiother Oncol* 2016; **121**(3): 468-74.
81. Defourny N, Perrier L, Borrás JM, et al. National costs and resource requirements of external beam radiotherapy: A time-driven activity-based costing model from the ESTRO-HERO project. *Radiother Oncol* 2019; **138**: 187-94.

Figure Legends

Figure 1 – Funnel plot demonstrating variation in rate of gastrointestinal toxicity across all NHS radiotherapy centres in England and Wales (n=55)

Figure 2 – Funnel plot demonstrating variation in bowel function scores using EPIC-26 Patient Reported Outcome Measure across all NHS Radiotherapy Centres in England and Wales (n=55)

Notes:

1. Higher adjusted mean scores using EPIC-26 Patient Reported Outcome Measure are associated with better bowel function

Figure 3 – Funnel plot demonstrating variation in sexual function scores using EPIC-26 Patient Reported Outcome Measure across all NHS Radiotherapy Centres in England and Wales (n=55)

Notes:

1. Higher adjusted mean scores using EPIC-26 Patient Reported Outcome Measure are associated with better sexual function

BOX 1 – Findings from the internal review and audit undertaken by negative and positive outliers following publication of radiotherapy treatment outcomes

Key considerations from negative outliers:

- The indicators have picked up toxicities not identified in the centre’s internal audits. Reason:
 - A significant proportion of referrals are made in the community by primary care teams
- Practices of care in line with recent trials (CHHiP study⁴⁶), however significant heterogeneity in centre-level radiotherapy protocols exist when comparisons undertaken
- Centres are using current standards in technology e.g. IMRT and IGRT (cone beam CT)
- Variation in practice between clinicians observed in the same centre e.g. doses to target structures, margins, and treating volumes (e.g. inclusion of pelvic lymph nodes)
- Physician peer review of contouring and dosimetry not routinely undertaken
- Training issues and lack of experience amongst gastroenterology teams outside of specialist centres, may potentially “over-call” radiation toxicities

Key considerations from positive outliers:

- No new technology or technique in use over and above standard of care that is readily available across other NHS centres
- Evolution of practice beyond trial protocols systematically undertaken to include:
 - Bowel protocols: diet plans and rectal enemas to minimise rectal volume
 - Contouring guidelines: Contemporary contouring guidelines for new trials integrated as standard of care across all patients e.g. PIVOTAL BOOST study
 - Treatment margins: Reduction in margins based on treatment set-up audit
 - Dosimetric constraints: Local adaptations to dosimetric constraints based on internal radiobiological modelling studies e.g. mean dose to rectum not to exceed 38Gy for patients receiving 60Gy in 20#
 - Image guidance: Use of fiducials routinely based on treatment set-up audit
 - Target localisation: MRI fusion

BOX 2 - Examples of Quality Improvement activities in response to public reporting of outcomes

- **Communication:** Improved communication between staff members both within radiation oncology groups and across disciplines (radiation therapists, medical physicists, dosimetrists)
- **Quality improvement teams set up:** Regular inter-disciplinary meetings set up to discuss nuances of practice including case selection, contouring, dosimetry and follow up processes.
- **Protocol and Institutional guidelines:** Updates of local prostate cancer radiotherapy practice protocols e.g. dosimetry, margins, bowel preparation
- **Internal audit of outcomes:**
 1. Audit of patients identified as having significant toxicity to assess entire process of treatment delivery to establish where improvements may be sought.
 2. Audit of treatment set-up and contouring to establish whether further reduction in margins are feasible and if fiducial markers should be considered
- **Peer review:** Implementation of routine peer review processes for contours and plans
- **Dosimetry:** Evolution of dosimetric guidelines – to tighter constraints guided by published research⁴⁷
- **Target localisation:** Evaluation of MRI guided planning
- **Image guidance:** Programme initiated for fiducial marker insertion
- **New technologies:** Consideration of peri-rectal spacers⁴⁸
- **Linacs:** Comparison of treatment set up and dosimetry between treatment machines in the e.g. Tomotherapy and VMAT to establish if differences exist
- **PROMs:** PROMs programme set up within individual centres to collate outcomes prospectively for radiotherapy patients
- **Training:** Improved training for staff members involved in patient assessment and follow up