Practical brachytherapy solutions to an age-old quandary

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Cancer is predominantly a disease of the elderly and as population life expectancy increases, so will the incidence of malignant disease. Elderly patients often have other comorbidities and social complexities, increasing the support required to safely deliver all treatment modalities. Brachytherapy is a relatively simple technique by which radiation therapy can be delivered. It offers dosimetric advantages through a highly conformal dose distribution thereby limiting radiation exposure to normal tissues reducing toxicity. Requiring fewer hospital visits, it also offers practical and logistical advantages to the elderly population and in many cases can be performed without the need for general anaesthesia. In tumour streams where brachytherapy forms part of the curative management, it should not be omitted in elderly patients who are medically fit for treatment. In the palliative setting, brachytherapy often offers an excellent means for achieving either local tumour and/or symptom control and should be actively considered in the therapeutic armamentarium of the oncologist in this context.

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Introduction

The World Health Organisation forecasts a doubling of the current population aged above 60 by 2050 meaning this cohort will make up 22% of the total global populace [1]. Concurrently, the burden of cancer in the ageing population has increased considerably and will continue to do so in the future posing a unique global healthcare challenge [2,3]. With increasing life expectancy and delayed presentation and diagnosis, due in part to cancer screening ineligibility, older patients with locally advanced disease will represent a greater proportion of patients seen in cancer clinics. There is no universally accepted definition of elderly. It ranges from a chronological time point of 65 years, biologically a deterioration of physiological functions and in some societies as the point when active contribution is no longer possible [4]. Older cancer patients are a heterogeneous group and concerted efforts need to be made by treating specialists such that the treatment decision process is not affected by unconscious bias as a function of chronological age [5]. Due to constraints within the current health care infrastructure appropriate assessment of the elderly patients with respect to frailty, comorbidities and psychosocial support is often inadequate [6–8]. In situations where a formal geriatric assessment is not available, short assessment tools may aid with fitness for treatment decisions but are still not in widespread use [9].

Radiotherapy has been the cornerstone of treatment in frail patients when surgery has been excluded but often a palliative approach is adopted over a curative one due to perceived intolerance of toxicity, despite a paucity of clinical trial data to support this. Whilst advances in the precision of external beam radiotherapy (EBRT) techniques minimise toxicities reported in earlier clinical trials, alternative treatment options such as brachytherapy may provide distinct advantages in this patient cohort. Consensus guidelines from the International Geriatric Radiotherapy Group have recognised brachytherapy as an ideal therapeutic modality in some circumstances but the radiotherapy task force of the International Society of Geriatric Oncology (SIOG) recommendations are more limiting [10,11]. Brachytherapy is a highly conformal treatment method designed to deliver radiation by placing radioactive sources close to or within a tumour. It takes advantage of one of the most fundamental principles of radiation physics (inverse square law) with distinct radiobiological advantages. The dose exponentially decreases with distance away from the source creating a very sharp drop-off hence either limiting or completely sparing the adjacent normal tissues from exposure to radiation. Brachytherapy can be interstitial with permanent radioactive seeds (low dose rate, LDR) or more commonly via a catheter delivery sys-
| Tumour site | Study (year) | Design | N | Median age (range) | Stage | Brachytherapy | Visits | EBRT | Median F/U (months) | Outcome | Toxicity |
|-------------|-------------|--------|---|------------------|-------|--------------|-------|------|---------------------|---------|----------|
| Gynecological | | | | | | | | | | | |
| | Kobayashi (2014) [22] | Case series (cervix) | 105 | 77 (70–89) | Ib-Iva | 6 Gy × 4 | 4–5 | 50 Gy/25–28 # | 59 | 5 yr CSS 78% | GI ≥ Gr 3.2%; GU 4.2% |
| | Coon (2008) [75] | Case series (endometrial) | 49 | 65 (31–91) | I–III | 4 Gy × 5 (if EBRT given) or 7 Gy × 5 bid | In-pt | 45–50 Gy/20–25# | 33 | 3 yr CSS 93% & OS 83% | 4/49 had late Gr 2 GI |
| | Nout (2010) [26] | PORTEC-2 Phase III (endometrial) | 427 | 70 | Ic – 2a | 7 Gy × 3 HDR or 30 Gy LDR VBT | 3 | 46 Gy/23# (control arm) | 45 | No diff in LRR or OS | significantly lower GI toxicity with VBT |
| Prostate | | | | | | | | | | | |
| | Satya (2005) [34] | Phase III | 104 | 65 (49–74) | Int. & high risk | 35 Gy over 48 hours HDR or 30 Gy LDR VBT | In-pt (2 days) | 40 Gy/20#/boost vs. 66 Gy/33# | 98 | 5-yr BRFS 71% vs 39%, p = 0.0024 | GI 6%/GU 4%/HR 13% vs 3%/2% NS |
| | Hoskin (2012) [33] | Phase III | 218 | 70 (47–80) | Int. & high risk | 17 Gy/2# in 24hrs | In-pt (2 days) | 35.75 Gy/13# + boost vs. 55 Gy/20# EBRT prostate | 85 | 7-yr BRFS 66% vs 48%, p = 0.04 | Severe GI 7% vs 6% NS |
| | Khor (2013) [76] | Matched case study | 344 | 67 (51–77) | T1–T3b | 6.5 Gy × 3 | In-pt (2 days) | 46 Gy/23# vs 74 gy/37# | 60.5 | 5-yr BRFS 79.8% vs 70.9% | Increased urethral stricture 0.3% vs 2.2% NS |
| | Morris (2016) [35] | Phase III | 398 | 68 (45–86) | Int. & high risk | 125I LDR boost (115 Gy) | In-pt (2 days) | 46 Gy/23# EBRT whole pelvis + 125I LDR boost vs 46 Gy/23# EBRT prostate boost | 78 | 9-yr BRFS 83% vs 62%, p < 0.001 | Late catheterization 12% vs 3%, p < 0.001 |
| Rectum | | | | | | | | | | | |
| | Yamazaki (2018) [77] | Case series (matched controls ≤ 75 yrs) Ph II (definitive) | 241 | 77 (75–86) | All risk (85% int & high) | All BT options (LDR, HDR monotherapy) | 2–9 | 74 Gy/37#/boost vs. 66 Gy/33# | 87 | 7 yr BRFS 94.9% elderly vs 96.4% younger (p = 0.6) LR 39%/11%/salvage TME OS 85% | Similar GI and GU in aged matched |
| | Dizdarevic (2019) [38] | Ph II (definitive) | 51 | 68 (61–77) | T2 or T3, N0–1 | 5 Gy (HDR) at 1 cm applicator surface single channel | EBRT = 6 weeks BT = 1 day | CTVp = 60 Gy/30# IMRT CTVn = 50 Gy/30# IMRT | 60 | 10 pts > 3Gr late toxicity (1 > Gr 4) | QoL score did not differ between baseline |
| | Rijkmans (2017) [39] HERBERT Dose escalation | Ph I (definitive) | 38 | 83 (57–94) | T2–4 N0–1 | 5–8 Gy × 3 (HDR) at 2 cm applicator surface multi-channel DLT ≥ 3 Gy proctitis < 6 weeks after HDREBRT | EBRT = 13 days BT = 3 days | 39 Gy/13#/EBRT (4/wk) | 24 | Recommended dose = 7 Gy per HDR L-PS = 42% OS = 63% | No difference in R0 resection PFS 63.9% vs 52.0%, (HR = 1.22, p = 0.32) OS 70.6% vs 63.6%, (HR = 1.24, p = 0.34) no difference in the prevalence of stoma |
| | Appelt (2015) [41] | Ph III (neo-adjuvant) | 221 | 63 (35–78) | T3–4 N0–2 M0 | 5 Gy × 2 (HDR) 1 cm applicator surface single channel | EBRT = 28 days BT = 2 days (incorporated) | 50.4 Gy/28#/5#/week | 65 | Complete response 58%; partial >50% response 27% | no difference in the prevalence of stoma |
| | Corner (2010) [40] | Case series (definitive & palliative) | 70 (52 definitive RT) | 82 (33–97) | ≥T2 | 6 Gy × 6 (HDR) monotherapy or 6 Gy × 2 (HDR) adjuvant 1 cm applicator surface single channel | Varied | 45 Gy/25# in 36 pts | NR | 6 pts late toxicity | No difference in the prevalence of stoma |
| Tumour site | Study | Design | N  | Median age (range) | Stage | Brachytherapya | Visitsb | EBRT | Median F/U (months) | Outcome | Toxicity |
|------------|-------|--------|----|-------------------|-------|---------------|--------|------|-------------------|---------|----------|
| Oesophagus | Vuong (2007) [42] | Ph II (neo-adjuvant) | 100 | N/R | T2-4, N0-1 | 6.5 Gy × 4 (HDR) 1 cm applicator surface single channel?? | 4 days | N/A | 60 | DFS 65% OS 70% 21pt had post-operative EBRT for pN1 | postoperative leak rate of 9% (5/45) abdominoperineal resection rate was 53% (51/96) and the sphincter preservation rate was 47% (45/96) 25 pts fibrotic strictures. Similar in both groups (p > 0.05) |
| Oesophagus | Sur (2002) [78] | Phase III Multicentre (palliative) | 232 | 56.8 | All stages | 8 Gy × 2 vs. 6 Gy × 3 at 1 cm source axis single channel (under sedation) | 2–3 | N/A | 8 | No difference between study groups | |
| Oesophagus | Homs (2004) [79] | Phase III multicentre (palliative) Stent vs BT | 209 | 69 | All stages | 12 Gy × 1 at 1 cm applicator surface single channel (under sedation) | 1 | N/A | 1 | long-term relief of dysphagia was better after BT | Stent vs. BT (33%) vs (21%); p = 0.02 |
| Oesophagus | Bergquist (2005) [80] | Phase III (palliative) Stent vs BT | 65 | 72 (60–82) | All stages | 7 Gy × 3 at 1 cm applicator surface single channel (under sedation) | 3 | N/A | 3 | Delayed with BT (1mo vs 3 mo) OS equivalent | No difference in toxicity. |
| Oesophagus | Rosenblatt (2010) [47] | Phase III (international, palliative) BT + EBRT vs. BT | 219 | 61.3 (15–102) | All stages | 8 Gy × 2 at 1 cm applicator surface single channel | 2 | 30 Gy/10# daily (Arm A) | 6.5 | DRE absolute benefit of + 18% at 200 days (p = 0.019); No difference in OS. At 3 wks improved dysphagia with stent + BT (p = 0.02); no difference at 7 wks | No difference in toxicity. 21/105 pts crossed over |
| Oesophagus | Amdal (2013) [81] | Phase III (palliative) Stent + BT vs stent | 41 | 71 (47–91) | T4No, T3N1, M1 | 8 Gy × 3 at 0.7 cm applicator surface single channel (under sedation) | 3 | N/A | 1.2 | | |
| LUNG | Zhu (2014) [82] | Phase III Multicentre (palliative) I125Stent vs stent Retrospective (inoperable & palliative) | 160 | 71 (60–79) | All stages | 15 Gy (range 10–31 Gy) 1 at 1 cm applicator surface single channel | Min 3 day stay | N/A | 4.6 | No difference in complication 1pt with oesophagotracheal fistula | |
| LUNG | Aggarwal (2015) [48] | Retrospective | 59 | 77 (53–88) | All stages | 15 Gy (range 10–31 Gy) 1 at 1 cm applicator surface single channel | 1–5 | 30 Gy/10# daily or 4.5 Gy × 6/1# per week | 28 | 89% improved dysphagia score. OS of all pts was 12.3 months; 1, 2 and 3 yr rates were 51, 19 & 7%. | 1pt oesophageal ulceration; 12 pts repeat endoscopy for symptoms post BT |
| LUNG | Stout (2000) [84] | Phase III (palliative) | 99 | 68 (40–84) | IV | 15 Gy × 1 at 1 cm applicator surface single channel | 1 | 30 Gy/10# (control arm) | NR | Improved dysphagia (85 vs. 45% P = 0.00085) Better global palliation with EBRT 59 vs. 83% P = 0.029 | Stricture 9 (15%), ulceration in 6 (10%), fistula in 3 patients (5%). No difference in toxicity |
| LUNG | Langendijk (2001) [53] | Phase III (palliative) | 95 | 67 | IIB tumour in main or lobar bronchus | 7.5 Gy × 2 at 1 cm applicator surface single channel (alone vs + EBRT) | 2 | Radical EBRT (60 Gy) or palliative EBRT (30 Gy) | NR | Improved dyspnea over time (P = 0.02) for main bronchus tumour. No diff OS | 2 pts with fistula in combination treatment |

(continued on next page)
Table 1 (continued)

| Tumour site            | Study Design | N         | Median (range) | Stage | Median F/U (months) | EBRT | Brachytherapy | Visits | Outcome | Toxicity |
|------------------------|--------------|-----------|----------------|-------|---------------------|------|---------------|--------|---------|----------|
|                        |              |           |                |       |                     |      |               |        |         |          |
| Breast                 | Phase III    | 142       | 62 (69–86)     | Phase III (palliative) | 8 Gy/C2 | 2–4 | 15 Gy × 2 to 3 cm | 4–5 | 50–0–50 Gy/C2 | 2–4 | No difference in LRR or OS | No difference in toxicity |
|                        | Phase III    | 1184      | 47 (33–86)     | Phase III (palliative) | 10 Gy/C2 | 2–4 | 15 Gy × 2 to 3 cm | 4–5 | 50–0–50 Gy/C2 | 2–4 | No difference in LRR or OS | No difference in toxicity |
|                        | Phase III    | 26        | 77 (69–89)     | Phase III (palliative) | 8 Gy/C2 | 2–4 | 15 Gy × 2 to 3 cm | 4–5 | 50–0–50 Gy/C2 | 2–4 | No difference in LRR or OS | No difference in toxicity |

BT = brachytherapy; DME = total mesorectal excision; DRE = dysphagia relief experience; DLT = dose limiting toxicity; DRE = dysphagia relief experience; HDR = high dose rate; IMRT = intensity modulated radiation therapy; LDR = low dose rate; LRR = local recurrence rate; MFS = metastatic free survival; PDR = pulsed dose rate; SBRT = stereotactic body radiation therapy; TME = total mesorectal excision.

Notes: * Unless stated otherwise; **: CT/EBRT, brachytherapy or EBRT + brachytherapy; all observed local recurrences were non-disseminated.

The upfront cost of setting up of a service coupled with lower reimbursement in some countries can make it an unattractive choice despite associations with improved survival [12]. In addition, the perceived workflow of brachytherapy compared to EBRT would require a radiation oncologist to dedicate a fixed time of 0.5–2 hours per patient versus shorter intervals over a period of 1–2 months for EBRT to include on-treatment review. Overall the clinician time per patient is likely to be less with brachytherapy [13]. Moreover, cost effective analysis is specific to each health care setting and conflicting depending on the model used. Comparison of costs in the USA for prostate treatment showed brachytherapy ($17 183) to be more cost-effective than SBRT ($27 145), IMRT ($37 090) and protons ($54 706), the latter of which is being delivered with a less robust evidence base [13,14]. In the UK, for high risk prostate cancer, a brachytherapy boost in combination with EBRT was found to deliver higher quality adjusted life years (8.82 vs 8.70) although at a slightly higher cost (£8591 vs £8225) compared to EBRT alone [15]. Similar cost-effectiveness has been reported for gynaecological malignancies and so citing financial toxicity as a barrier to brachytherapy is not credible [16,17].

This review summarises the evidence for brachytherapy in common malignancies affecting the elderly population, highlighting and questioning its underutilisation based on clinical outcomes and toxicity profiles in this age group both in the definitive and palliative setting. The focus will be on the most common malignancies in the elderly where radiotherapy is indicated; lung, breast, prostate, rectum and corpus uteri whilst recognising that brachytherapy can also be applied to a wider range of tumour sites such as skin, head and neck, liver and connective tissue cancers.

Search strategy

A literature search was used to examine relevant English language publications from PubMed supplemented by hand-searching of abstracts from recent international meetings. Key words used include “brachytherapy”, “elderly” “geriatric”, and “palliative” excluding reviews, editorials and commentaries from January 2000 to June 2020. Additional publications were identified by scanning references. Studies relevant to common solid tumours in the elderly population where brachytherapy may be indicated were identified. Studies using contact X-ray and where the median age was <60 for curative intent treatment were excluded. Table 1
summarises the brachytherapy studies pertinent to the elderly population.

**Gynaecological cancer**

The underutilisation of brachytherapy in locally advanced cervical cancer globally is widely recognised and this effect is more pronounced in the elderly population with studies from North America reporting 20% of women between ages 70–79 and up to 60% of women >80 years old not receiving brachytherapy [18,19]. Analysis of the cooperative oncology group studies (COG) clinical trials consisting of the largest stage IVA patient populations in the literature reported, brachytherapy was not completed in 35% of patients ≥70 years versus 13% of patients <40 and this is despite the fact that these clinical trials are undertaken at large tertiary centres where brachytherapy programmes are well established [20]. By contrast, neither the chemotherapy dose, number of chemotherapy cycles delivered nor the overall radiation treatment time were compromised due to increasing age [20]. Where poor renal function and cardiac comorbidities preclude concurrent chemotherapy, patients are often treated with EBRT alone without consideration of the brachytherapy boost. Medical comorbidities and anaesthetic risk are often cited as reasons for omission, however no formal anaesthetic risk assessments were conducted in these clinical trials. In addition, cervical brachytherapy procedures can be undertaken under regional or local anaesthesia and the number of fractionations and the treatment workflow can be tailored to the patient to maximise comfort [21]. A retrospective cohort series specifically addressing the impact of CT-based brachytherapy in 105 elderly patients (70–89 years) reported 5-year local control and cancer specific survival rates of 89% and 78% respectively with comparable toxicity profile to younger cohorts [22]. Brachytherapy is an essential component of cervical cancer (>Stage IB) and should not be omitted in elderly patients unless medically unsuitable. Unlike other solid tumours where brachytherapy is an alternate option, in cervical cancer it is a mandatory component of curative intent treatment and should not be substituted with EBRT or SBRT boosts which have poorer outcomes [23].

The peak age of endometrial cancer in the UK is 75–79 years with 27% of new cases in >75 years. In recent years the PORTEC and GOG trials have shaped practice in the post-operative setting in which almost half of the patients were >70 years old [24-26]. It was also this age group (≥70 years old) that had the highest rate of local recurrences in both trials. Vaginal vault brachytherapy (VBT) in the adjuvant setting is a practical method of treatment with minimal toxicity and well tolerated by older patients which if indicated should be offered. A retrospective review of patients ≥70 years found that FIGO stage and higher age resulted in less aggressive treatment being offered. Comorbidity on the other hand did not influence treatment choice highlighting the apparent discrepancies in the basis of oncological treatment decisions, particularly with respect to frailty, and the lack of evidence in the older age group [27]. The benefit of adjuvant chemotherapy combined with VBT for tumours with a high recurrence risk is unclear and the topic of ongoing trials. In the primary setting, brachytherapy either in combination with EBRT or in isolation using Heyman or Rotte applicators is effective for inoperable endometrial cancer [28,29] and this strategy should not be overlooked in elderly patients presenting with advanced stage disease.

**Prostate cancer**

Prostate cancer ranks as the second leading cause of death in men in developed countries. As life expectancy increases the diagnosis and management of prostate cancer in men >75 will represent an increasing challenge [30]. Radiotherapy trials that have informed best practice in prostate cancer have rarely included men greater than 80 years of age mainly due to the “watchful waiting” approach that is adopted in this age group [31]. In the curative setting, radiotherapy which can be EBRT, brachytherapy or SBRT is often the treatment of choice over surgery for elderly men with prostate cancer. Brachytherapy can be used in localised prostate cancer as a single modality treatment or as a boost in high risk localised disease. This is achieved with either permanent implant LDR radioactive seeds or HDR brachytherapy. Aside from the radiobiological gains of brachytherapy in a tumour with a relatively low alpha/beta ratio, it is also financially more viable both in set-up and maintenance than protracted courses of EBRT, particularly advantageous in low- and middle-income countries. Furthermore, it can significantly reduce the number of hospital visits, an additional benefit especially in the elderly population. In the setting of high-risk prostate cancer, fit elderly patients should be offered curative intent treatment. Despite the aforementioned advantages prostate brachytherapy is underutilised and this trend is pronounced in the elderly population [32]. Three randomised controlled trials (RCT) have shown significantly improve biochemical recurrence-free survival across all risk groups where a brachytherapy boost is delivered in combination with EBRT compared to EBRT alone, with no clinically significant difference in prevalence of late toxicity [33-35]. In carefully selected patients LDR seeds or two fraction HDR brachytherapy monotherapy has excellent local control rates even in high risk disease [36,37]. Salvage treatment for localised recurrence, although still in its infancy is being increasingly utilised in preference to prostatectomy with PSA-MET imagining improving staging and patient selection, and the use of rectal spacer devices reducing rectal dose in the setting of re-irradiation. Brachytherapy is a safe, feasible and effective option for fit elderly men and should be considered following a formalised assessment for fitness and life expectancy.

**Rectal cancer**

Brachytherapy does not form part of the standard multimodal approach to rectal or anal cancer. However, organ preservation approaches to lower GI tumours have explored dose escalation with brachytherapy as an alternative to surgical management with encouraging results [38,39]. The main indication for brachytherapy in the elderly population with ano-rectal tumours is in those who are unfit for standard care with palliative options being offered for inoperable, locally advanced and recurrent disease. Endoluminal single or multi-channel applicators or alternative single line source catheters in the case of significant canal stenosis either alone or in combination with EBRT provides effective local control with rectal bleeding complete control in 65% of patients with 50% achieving complete pain control [40]. Palliative single dose (10 Gy) can be delivered to frail patients minimising hospital visits and the need for repeated treatments.

Pre-operative brachytherapy delivered in four fractions in a phase II trial resulted in pCR of 29% and DFS of 65%. However a RCT comparing preoperative CRT vs CRT plus HDR boost did not demonstrate a benefit of combination treatment although criticism is levied at the relatively low HDR dose prescribed based on radiation dose response models in rectal cancer [41-43]. Despite the limitation in the early phase studies presented in Table 1, avoidance of colostomy with good sphincter preservation rate and local progression free survival makes this an extremely viable option for the older cohort of patients which ought to be considered. Given the major lifestyle challenges for elderly patients faced with a colostomy inclusion of the patient and their family with full presentation of the relative merits of different approaches is essential [44].
Oesophageal cancer

Annually 41% of all new oesophageal cancer cases in the UK are diagnosed in people aged ≥75 [45]. Intraluminal brachytherapy alone or in combination EBRT provides durable functional improvement in patients assessed to be unfit for curative intent treatment with surgery or combined modality treatment. A Cochrane systematic review on interventions for managing dysphagia reported that although self-expanding metallic stent (SEMS) provided immediate relief of symptoms combination of HDR brachytherapy with SEMS or EBRT reports a survival advantage, reduced requirement for re-interventions and possibly a better quality of life [46]. The largest RCT which compared HDR brachytherapy alone or in combination with EBRT demonstrated a significant benefit in the primary endpoint of dysphagia in favour of combination treatment, though no overall survival advantage [47]. Given the low median survival in the palliative setting promptly treating dysphagia through accessibility to brachytherapy ± SEMS can have a significant impact on QoL. The procedure is very feasible in the elderly population. It can be straightforward, quick, inexpensive and often performed without sedation using a nasogastric tube preloaded with an HDR after loading catheter and a single line source on an outpatient basis completed in a single visit in a couple of hours [48,49]. An alternative method is a fluoroscopic/laparoscopic guided procedure combined with placement of SEMS, more suitable for multiple fractions. Currently there is no consensus on optimal treatment schedules but treatment protocols from RCT require 7–12 Gy/fraction in 1–3 fractions. Randomised trial toxicity data suggest brachytherapy is comparable to stent placement although a prolonged hospital stay in the stent group has been reported (Table 1). It is recommended that palliative oesophageal cases be discussed with a brachytherapist particularly if following comprehensive assessment, the life expectancy of patients for example, those who have previously received EBRT and later between the studies [51]. The EORTC Elderly Task Force opinion paper has acknowledged the omission of adjuvant brachytherapy although there was considerable heterogeneity in the failure in part to show a benefit over whole breast EBRT yet its benefit remains unclear [52]. The use of LDR interstitial isotopes requiring general anaesthesia and specialised brachytherapist input. The failure in part to show a benefit over EBRT in non-operable cases has been on the decline over the past decade despite improved disease specific survival and local control rates with combination treatment [64,65]. A small mixed case series in vaginal cancer showed a trend for improved outcome with combination treatment [66]. Brachytherapy is also a good option in the salvage setting for vaginal recurrence in endometrial cancer with 3-year recurrence free survival at 68% and actuarial rate of late grade 3 toxicity at 8% [67].

Addressing barriers to brachytherapy

The barriers to brachytherapy uptake is a global issue and not limited to the elderly population and the onus rests with the radi-
atication community to address the limitations in order to ensure patients are offered the most appropriate radiotherapy modality. A key area that require education is training in brachytherapy.

Developing a brachytherapy curriculum relevant to the global community focusing on the theory beyond current training programs and implementing competency based procedural training would be beneficial for the specialty. Relevant aspects to the elderly population can then be integrated into the global radiotherapy curriculum for elderly cancer patients [71]. The IAEA is currently working on a global curriculum using the CanMEDS framework for brachytherapy professionals however practical training with most countries adopting centralised brachytherapy services still remains a challenge [72]. Competency-based practical training has been recently reported in prostate and cervix brachytherapy with pilot studies consisting of eight trainees. The prostate brachytherapy competency domains were assessed on transperineal rectal spacer placement patients and the cervix on gynecological training pelvic models using tandem and ovoid applicators. Both studies reported an improvement in trainee confidence with the students participating in the cervix study reducing their implant execution time by 10.5% [73,74]. Incorporation of similar training programmes at a national level will address the current issue of low numbers of brachytherapist and not offering brachytherapy as a treatment option to patients. In addition, integrating current coursework materials from international brachytherapy societies, using novel planning-based software with integrated feedback and simulation-based training environments are all tools that should be incorporated in a comprehensive programme. Furthermore, opportunities to undertake dedicated brachytherapy fellowships is currently limited with seven centres in the USA and a collaborative international fellowship in the UK. Other high throughput brachytherapy centres need to establish brachytherapy fellowships for local and international candidates to upskill future radiation oncologists.

Other barriers to improve brachytherapy uptake is to diversify current working models to one that is team-based and not tumour site specific, ensuring the brachytherapist are proficient across tumour types and to improve advocacy around brachytherapy in particular to address the reimbursement paradox.

Conclusion

The treatment of older patients with cancer continues to present a challenge, as very little high-level evidence exists to guide management. This review highlights the benefits of definitive and palliative brachytherapy in the older population. In aged or frail patients, a comprehensive geriatric assessment is recommended when evaluating individual patient fitness for brachytherapy alongside tumour biology, potential toxicities, physiological age, patient preference, quality of life, and remaining life expectancy.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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