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An analysis of a satellite oncological radiotherapy unit in the Canary Islands: a cost-minimisation study

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Abstract

Background Radiotherapy access remains inequitable, particularly in geographically isolated regions such as island territories, where centralisation of services often requires long-distance travel for patients. This imposes substantial burdens on patients and their families, potentially resulting in treatment discontinuation or refusal. Decentralised service models, such as satellite radiotherapy units, have emerged as a promising strategy to bring care closer to underserved populations while preserving integration with centralised expertise. However, decentralisation also poses several challenges, including underutilisation, resource duplication, and higher operational costs. In 2022, a satellite radiotherapy unit was established in Fuerteventura (Canary Islands, Spain) to promote equitable access to cancer patients. The economic impact of this unit has not yet been evaluated.

Objective To compare the cost of delivering radiotherapy at the satellite unit of Fuerteventura with the cost at the reference centre in Gran Canaria for patients living in Fuerteventura.

Methods A cost-minimisation analysis was conducted from the perspective of the public health system using 2021 and 2023 data. Direct healthcare costs were estimated based on the annual costs of each facility, adjusted for treatment complexity and volume. Travel-related costs were derived from reimbursement data, including inter-island transport, accommodation and transfers for in-hospital patients. Costs per patient were compared, and the patient volume required for the satellite unit to generate cost-savings was calculated.

Results In 2023, 182 patients received radiotherapy at the Fuerteventura unit, compared to 2,501 at the reference centre in Gran Canaria. The average healthcare cost per patient was €6,855 at the satellite unit and €4,619 in Gran Canaria. However, average travel costs per patient dropped from €1,819 in 2021 (before the satellite unit) to €337 in 2023. Overall, total per-patient cost was €754 higher at the satellite unit in 2023. Our estimates suggest that the unit may generate cost-savings for the healthcare system once patient volume reaches 205 patients per year—a threshold already exceeded in 2024.

Conclusions The satellite model demonstrates potential to deliver cost-comparable care as patient volumes increase. Moreover, improved proximity to treatment may offer additional access-related benefits, as suggested by

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previous literature, reinforcing the value of satellite models in promoting equitable access while maintaining high standards of care.

Keywords Cancer, Radiotherapy, Cost-minimisation analysis, Geographical accessibility, Equity

Background

Radiotherapy is a fundamental component of multidisciplinary cancer treatment, indicated for approximately half of all cancer patients throughout their illness [1]. It contributes substantially to cancer cure rates (around 40% of cured cases) and is considered a highly cost-effective treatment option [2]. However, in many regions, including Spain, the utilisation of radiotherapy treatments remains below clinical need, partly due to geographical barriers that limit patient access [3]. Distance from specialised cancer centres has been associated with advanced stage at diagnosis, lower likelihood of receiving treatment, and worse survival outcomes for patients [4–7]. Moreover, and beyond clinical endpoints, studies have found that cancer patients living far from treatment facilities experience poorer quality of life outcomes compared to those with closer access [8].

These inequalities highlight the critical issue of geographical accessibility in cancer care, as patients living in remote areas often face limitations in accessing modern treatments that enhance survival rates and quality of life. Geographical barriers to healthcare are especially pronounced in archipelagos and island territories. In such settings, specialised oncology centres are typically located on a main island or urban hub, leaving residents of smaller or more remote islands with limited local services. Patients often have to travel by ferry or plane to reach radiotherapy facilities—sometimes on a daily basis over the course of several weeks of treatment. This was historically the case for cancer patients from Fuerteventura, in the Canary Islands, Spain, which lacked a local radiotherapy unit until 2022.

Before 2022, Fuerteventura residents (with a total population of over 120,000 inhabitants) in need of radiotherapy treatment had to transfer to the neighbouring island of Gran Canaria (with over 860,000 inhabitants) to receive treatment at the tertiary oncology centre. Such inter-island travel, whether undertaken daily or via a temporary relocation of residence, might incur in significant financial and social costs. Patients and their families faced expenses for transportation, accommodation, and meals, which were reimbursed by the public health system, i.e., the Canary Islands health service (Servicio Canario de la Salud, SCS). Other expenses, such as lost income, childcare or other dependants' caregiving costs were not covered by the SCS. The physical fatigue of travel and the emotional strain of separation from home and support networks may have an additional burden to these patients, detracting from patients' quality of life. In some cases, logistical difficulties reportedly contributed to treatment delays or refusal, particularly among palliative patients where the goal is symptom relief rather than cure. This situation illustrates how geographic isolation may contribute to unequal access to cancer care, potentially affecting treatment uptake and outcomes.

Decentralised and satellite radiotherapy service models have been increasingly studied from various perspectives to assess their viability, cost-effectiveness, and impact on patient access, experience and outcomes. Previous literature has demonstrated that decentralisation can improve access to healthcare and increase utilisation rates, particularly in geographically remote regions [9, 10]. By bringing specialised services closer to patients, these models have been argued to reduce patient travel time, generate cost savings for patients and the healthcare system, and enhance patients' quality of life [11]. Furthermore, comparing three radiotherapy service delivery models: a fully centralised system, a fully decentralised system, and a central facility with satellite configuration, Dunscombe & Roberts, 2001 found that the satellite model was the most cost-effective option from a societal perspective when patient travel distances exceeded 170 km [12].

In June 2022, a satellite radiotherapy unit was established at the General Hospital of Fuerteventura (HGF) as a strategy to ensure more equitable access to cancer treatment on the island. The facility operates as part of the radiotherapy oncology department based in Gran Canaria, with a specialised team of oncologists responsible for patient care. However, despite its expected benefits, decentralisation can also pose several challenges, such as the risk of underutilisation, resource duplication, and higher operational costs, particularly when patient volumes are low or technical complexity is high. These considerations highlight the need for strategic planning to ensure that satellite units deliver sustainable improvements in access while maintaining high standards of care.

Given these considerations, a comprehensive assessment is essential to understand the economic and societal implications of establishing a satellite radiotherapy unit in Fuerteventura. The aim of this study is to provide a comparative analysis of the cost of delivering radiotherapy at the newly established satellite unit at the HGF with the cost of providing the same treatments at the reference centre, the University Hospital of Gran Canaria Dr. Negrín (HUGCDN), for patients living in Fuerteventura. The analysis considers both direct healthcare and non-healthcare costs. We use cost data from the SCS to assess the direct economic impact from the health system

perspective, including the operational costs of the new unit, and transport and accommodation expenses saved. This information allows us to quantify the incremental per patient and annual cost associated with treatment at the HGF radiotherapy unit and to explore the number of patients that need to be treated at the satellite unit for the centre to generate cost-savings to the healthcare system.

The following section outlines the study setting, along with the data sources and methods used in the economic analysis. The subsequent section presents the results, including the estimated incremental healthcare and non-healthcare costs associated with the radiotherapy satellite unit. The Discussion section examines the implications for patients and carers, as well as other broader social impacts associated with bringing radiotherapy services closer to patients' residence, drawing on relevant literature. It also considers the implications of our findings for the strategic planning of oncology services in geographically remote areas.

Methods

Study setting: Fuerteventura satellite radiotherapy unit

This analysis was conducted in the context of a newly established satellite radiotherapy unit on the island of Fuerteventura, Canary Islands, Spain. The unit at the HGF began operating in June 2022. It is equipped with a single medical linear accelerator and is an extension of the radiotherapy oncology department of the HUGCDN. The satellite unit has a permanent local team, while radiation oncologists from the reference hospital provide services through regular rotations.

Under this system, patients from Fuerteventura first attend for an initial consultation at HUGCDN in Gran Canaria, where the radiation oncologist confirms the indication for radiotherapy and the treatment technique. Additionally, treatment planning is centralised at HUGCDN, with the exception of patients with palliative care, who are assessed and planned at the HGF. In the satellite unit, external radiotherapy treatments are administered using 3D conformal radiotherapy (3DCRT), volumetric modulated arc therapy (VMAT), and stereotactic body radiotherapy (SBRT) techniques. High complexity treatments and other techniques such as brachytherapy and intraoperative radiotherapy (IORT) remain available only at the reference centre in Gran Canaria. Nevertheless, the satellite covers the majority of common radiotherapy indications, allowing most Fuerteventura patients to complete their treatment locally. Follow-up consultations also take place at the satellite unit. The same oncology specialists oversee care across both sites, following unified clinical protocols to ensure consistent treatment quality and outcomes.

Economic evaluation – cost-minimisation analysis

The analysed model combines the expertise of the reference hospital with the accessibility of local care delivery, and for this reason, the analysis adopts a cost-minimisation approach, assuming no significant differences in clinical effectiveness between the two locations. The limitations of this approach are discussed at the Discussion section which provides an overview of the potential benefits of the proximity to radiotherapy care on patients and their relatives as well as other broader implications, based on previous literature.

The cost-minimisation analysis compared the per patient cost of receiving radiation therapy at the satellite unit with the cost of receiving the same treatment at the reference centre for patients living in Fuerteventura. The analysis was performed from the perspective of the public health care provider, i.e., only costs incur by the SCS were included. We obtained annual cost data for the year 2023 from the SCS for both the HGF satellite service and the HUGCDN radiotherapy oncology department, as well as information on patients' travel and accommodation expenses reimbursed by the SCS in 2021 (prior to the establishment of the satellite unit) and in 2023 (when the unit was operating throughout the year). Data on the costs of bed-to-bed patient transfers was also retrieved for these two years. Information on the number of patients treated by treatment type were obtained from hospital records. All costs are expressed in 2023 Euros. The calculations of the average direct healthcare and non-healthcare cost per patient for each setting are detailed next.

Direct healthcare cost per patient

We computed the direct healthcare cost per patient as the total annual healthcare costs attributable to equivalent radiation therapies divided by the number of patients who started equivalent radiation therapies in 2023 at each site:

$$Direct\ Healthcare\ Cost_{PP} = \frac{Total\ annual\ healthcare\ cost\ of\ equivalent\ radiation\ therapies}{Number\ of\ patients\ starting\ equivalent\ radiation\ therapies}$$

Equivalent radiation therapies were defined as those available at HGF, namely 3DCRT, VMAT, and SBRT. Accordingly, the denominator in the above cost per patient formulae for the satellite unit corresponds to the total number of patients who initiated treatment in 2023 at the HGF[1]. For the HUGCDN, patients receiving

[1] Note that by focusing on the number of patients who initiated treatment during the year, the analysis excludes from the denominator patients who

advanced techniques not offered at the Fuerteventura unit were excluded from the denominator to ensure comparability. Although some patients may have received more than one course of radiotherapy, the analysis assumes one treatment per patient.

Regarding the numerator, the cost components included staff costs (covering both local staff and visiting specialists in the case of the HGF), operational costs (such as depreciation, pharmaceuticals, consumables, and medical supplies), and other costs (including laboratory tests, imaging, outpatient consultations, and inpatient stays). With regard to the equipment and room depreciation costs, the acquisition cost of the lineal accelerator and the cost of adapting the radiotherapy bunker at the HGF was used to estimate the annual depreciation costs for the satellite unit, assuming a useful life of 10 and 68 years, respectively. At HUGCDN, amortization was estimated considering its five linear accelerators used for equivalent treatments, applying the same unit cost as that estimated for the satellite unit at HGF. This approach was used to exclude depreciation costs for equipment at the HUGCDN not used in treatments equivalent to those provided at HGF.

Furthermore, to enable a comparable estimation of the healthcare cost per patient treated at both HGF and the HUGCDN, the total healthcare costs of the HUGCDN needed to be refined to capture only the costs associated with treatments that are also provided at the HGF. To do so, the proportion of the total activity provided at the Gran Canaria radiotherapy oncology department attributable to treatments available in Fuerteventura was estimated. This was necessary because, while detailed data on the number and type of treatments performed are available, disaggregated cost data by treatment type are not. Therefore, the estimation relied on activity-based approximations to identify the share of total service costs corresponding to treatments equivalent to those provided at HGF. To this end, all activity schedules within the HUGCDN radiotherapy oncology department were analysed to identify procedures that are not equivalent to those delivered at HGF. The analysis excluded treatments such as brachytherapy, IORT, cerebral radiosurgery (including all CyberKnife treatments), SBRT with breath-holding techniques, total body irradiation, Calypso-guided therapy, paediatric radiotherapy and craniospinal radiotherapy, as well as activities related to chemotherapy, hyperthermia, and hyperbaric chamber treatments. In addition, the number of medical consultations and follow-up visits associated with these non-equivalent treatments was estimated proportionally to the number of excluded treatments. Specifically, it was estimated that 25% of the treatments indicated in Gran Canaria in 2023 were not available in Fuerteventura. Accordingly, both these treatments and 25% of the total consultations and follow-up appointments were excluded from the cost analysis. To refine this estimate, each treatment type was first weighted by its relative resource intensity using a complexity level classification based on a consensus-based proposal on external radiotherapy and brachytherapy [13], supported by expert input. Annex 4 shows the assigned complexity levels. Treatments not specifically classified were assumed to correspond to level 1. This weighting allowed us to estimate the share of HUGCDN's annual costs corresponding to activity equivalent to that of the satellite unit at HGF.

After determining the total annual cost of equivalent radiation therapies for each site, we divided it by the number of patients who began equivalent radiation therapies in 2023 at each site to obtain the direct healthcare cost per patient at the HGF and the HUGCDN, respectively.

Direct non-healthcare (travel) cost

We considered patients' and companions' transport and accommodation expenses reimbursed by the health system. We obtained data on these non-healthcare costs for Fuerteventura residents treated at the HUGCDN radiotherapy oncology department from the SCS "Sistema de Información de Prestaciones" (SIPRE) database, which records travel expenses reimbursed. The data included all costs covered by SCS: inter-island transport (airfare or ferry tickets), local transportation in Gran Canaria (e.g. taxis or buses), accommodation (hotel or hostel nights), and meal stipends for patients and accompanying persons. Accommodation and subsistence expenses reimbursed by the Canary Islands Health Service are regulated through officially established maximum compensation amounts[2]. In addition, we considered the costs of transferring in-hospital patients from Fuerteventura to Gran Canaria (including medically supported flights and ambulance costs). We calculated the average travel cost per patient by dividing the total annual amount by the number of Fuerteventura patients who initiated radiotherapy treatment in that year (regardless of treatment type), as below:

$$Non-healthcare\ cost_{pp} = \frac{Total\ annual\ travel\ cost}{Number\ of\ patients\ stating\ radiation\ therapies}$$

began treatment in a previous year but completed it during 2023. This approach assumes that patients who started treatment in 2022 and continued into 2023, or began in 2023 and continued into 2024, are effectively balanced out.

[2] https://www3.gobiernodecanarias.org/sanidad/scs/content/84bf1211-73a6-11e8-8185-c598b419aac1/Orden_4junio2018_compensaciones.pdf.

Table 1 Annual and per patient costs of radiotherapy treatment at HGF and HUGCDN in 2023

Healthcare costs	HGF	HUGCDN
Annual cost of the radiotherapy oncology service		
Staff	509,736 €	7,043,664 €
Operating costs (excluding amortization)	302,983 €	2,579,383 €
Amortization	235,192 €	1,175,959 €
Other	199,762 €	4,151,628 €
Total annual healthcare cost	1,247,673 €	14,950,634 €
Total annual healthcare cost for equivalent radiation therapies	1,247,673 €	11,553,057 €
Number of patients starting equivalent radiation therapies	182	2,501
Healthcare cost per patient	**6,855 €**	**4,619 €**

Notes: HGF = Hospital General de Fuerteventura; HUGCDN = Hospital Universitario Gran Canaria Doctor Negrín

Table 2 Annual and per patient travel and accommodation costs in 2021 and 2023

Non-healthcare costs	With unit at HGF (2023)	Without unit at HGF (2021)
Annual non-healthcare costs (travel & accommodation)	67,068 €	287,109 €
Number of Fuerteventura residents starting treatment*	199	172
Non-healthcare cost per patient	**337 €**	**1,819 €**

Notes: HGF = Hospital General de Fuerteventura; HUGCDN = Hospital Universitario Gran Canaria Doctor Negrín

*These number includes patients starting equivalent and non-equivalent radiation therapies

In this case, the denominator includes all patients living in Fuerteventura who started any radiotherapy treatment in that year. The reason is that it was not possible to attribute travel costs to patients initiating equivalent treatments only. This approach assumes that patients requiring therapies available only in Gran Canaria incur similar travel costs as those who receive the treatments that are available at HGF.

Non-healthcare cost per patient was computed for two scenarios: for the period prior to the satellite unit (using 2021 data, when all Fuerteventura patients had to travel to Gran Canaria for radiotherapy) and for the period post implementation of the satellite unit (using 2023 data, when patients still required an initial consultation in Gran Canaria - except for palliative cases - but most subsequently received treatment in Fuerteventura). Thus, data for 2021 represents the annual travel burden in the absence of a satellite service, while data for 2023 represents the travel costs when the satellite unit was in operation. The difference in average travel cost between 2021 and 2023 was used to proxy the travel expenditure savings per patient due to the new satellite unit. It should be noted that other indirect costs (such as patients' productivity losses or paid/unpaid caregiving time) were not included in our analysis, which takes the public health system perspective; however, such factors are considered in the Discussion section.

Results

Table 1 presents the total cost of the radiotherapy oncology service at HGF and HUGCDN in 2023. In Fuerteventura, the cost amounted to €1.25 million, while in Gran Canaria it reached nearly €15 million.

The acquisition cost of the linear accelerator was €2,322,650, and the cost of adaptation of the radiotherapy bunker at HGF was €199,020. Assuming the useful life mentioned in the methodology section, we obtained an annual amortization cost of €235,192 per lineal accelerator. Based on activity weighted by treatment complexity, it was estimated that 75.3% of the procedures performed in 2023 at the Gran Canaria radiotherapy oncology department corresponded to treatments also available in Fuerteventura. Therefore, the annual cost of the HUGCDN service (excluding amortization) was multiplied by this percentage to estimate the cost attributable to radiotherapy treatments equivalent to those provided at HGF. This was estimated at €11.55 million (adding amortization costs).

The number of patients who initiated an equivalent radiotherapy treatment—defined as 3DCRT, VMAT, and SBRT—in 2023 was 182 at HGF and 2,501 at HUGCDN. Accordingly, the estimated cost per patient receiving radiotherapy treatment was €6,855 at HGF and €4,619 at HUGCDN.

With regard to non-healthcare costs related to patient and companion travel and accommodation covered by the SCS and transfer for in-hospital patients, the total cost in 2021 was €287,109, while in 2023 it was €67,068 (Table 2). These costs were divided by the total number of Fuerteventura residents who initiated any radiotherapy treatment at either unit in 2021 and 2023, respectively. This results in a non-healthcare cost per patient of €1,819 in the absence of the satellite unit, and €337 when the satellite unit was in operation.

Table 3 compares the cost of radiotherapy treatment in Fuerteventura and Gran Canaria, presenting both per

Table 3 Annual and per patient incremental costs of radiotherapy treatment at HGF and HUGCDN

	HGF	HUGCDN	Incremental cost per patient	Incremental annual cost (assuming 182 patients/year)
Healthcare cost per patient	6,855 €	4,619 €	2236 €	406,947 €
Non-healthcare cost per patient	337 €	1,819 €	-1,482 €	-269,805 €
Total cost per patient	**7,192 €**	**6,231 €**	**754 €**	**137,141 €**

Notes: HGF = Hospital General de Fuerteventura; HUGCDN = Hospital Universitario Gran Canaria Doctor Negrín

patient costs and the annual costs, assuming that 182 patients begin treatment in Fuerteventura, based on 2023 data. Healthcare costs per patient is €2,236 lower at HUGCDN compared to HGF, while non-healthcare costs (transport, accommodation, and meals) are €1,482 lower when treatment is received at HGF. As a result, the total cost per patient was €754 higher when treated at satellite unit than when the patient is treated at HUGCDN in 2023. At the annual level, based on 182 patients, the increase in healthcare costs is estimated at €406,947, partially offset by a €269,805 reduction in non-healthcare costs, resulting in a net additional cost of €137,141 in 2023.

Based on these estimates, and assuming that total costs remain the same, the number of patients needed to be treated at the HGF satellite unit for the unit to generate cost-savings for the SCS is estimated in 205 patients/year.

Discussion

This study evaluates the economic implications of establishing a satellite radiotherapy unit on the island of Fuerteventura, using a cost-minimisation framework. The results show that while the healthcare cost per patient treated at the satellite unit is €6,855, compared to €4,619 at the reference hospital, this higher medical cost is partially offset by savings in non-healthcare costs, related to inter-island travel and accommodation, which decreased from €1,819 to €337 per patient after the satellite unit began operating. The total cost per patient treated at Fuerteventura remains €754 higher in 2023, amounting to an annual incremental cost of €137,141 for 182 patients.

The difference in healthcare costs observed between the two facilities is primarily attributable to the disparity in patient volumes: in 2023, the reference centre in Gran Canaria initiated 2,501 equivalent treatments, compared to 182 at the satellite unit in Fuerteventura—a 14-fold difference. As demonstrated in this study, the high patient volume at HUGCDN enables economies of scale, resulting in lower per-patient costs for radiotherapy treatment. Consequently, while the cost per patient was higher at the satellite unit in its first full year of operation, this difference is expected to narrow as the unit becomes more established and patient volumes increase. Our analysis indicates that cost-savings would be generated once the satellite unit treats more than 205 patients annually. According to hospital records, the satellite unit activity level in 2024 has already reached the projected threshold, with 210 radiotherapy treatments initiated during the year. In parallel, the population of Fuerteventura has more than doubled since 2000, growing from 60,124 to 128,744 inhabitants—an average cumulative growth rate of 3.2% per year. If this demographic trend continues, the satellite unit is likely to remain the minimum-cost solution for delivering radiotherapy services. Moreover, the associated cost advantage is expected to increase over time.

A key limitation of our analysis is that it employs a cost-minimisation approach and adopts a healthcare system perspective, rather than a cost-effectiveness framework and a broader societal perspective. The reason for opting for a cost-minimisation study was due to the lack of comparative data on clinical outcomes between Fuerteventura patients treated before and after the establishment of the satellite unit. As a result, in this study we could not evaluate the quality of life and cancer outcomes provided at the satellite unit compared to the reference cancer centre. In the absence of such information, we assumed, conservatively, that effectiveness was the same across both sites. This is because the satellite unit benefits from a robust organisational model, in which radiation oncology specialists from the reference centre rotate to ensure continuity of care. This model also ensures consistent clinical protocols and treatment standards while promoting the integration of tumour boards and multidisciplinary decision-making at the satellite unit, warranting that patients treated at the satellite unit received the same standards of care as those in the reference hospital.

However, there is empirical evidence of the clinical benefits associated with proximity to radiotherapy services which are not accounted for in our analysis. Several studies have shown that living closer to a treatment centre significantly impacts patients' quality of life, treatment adherence, and even survival outcomes. For instance, Thomas et al. 2015 found that cancer patients living farther from treatment centres, particularly women, experienced worse physical functioning and greater difficulty with daily activities [8]. Lin et al., 2016 and Voti et al., 2006 reported that longer travel distances reduced the likelihood of receiving radiotherapy, directly affecting treatment decisions and outcomes [6, 7]. Beckett et al., 2023 and Baade et al., 2011 further confirm a positive association between distance to radiotherapy centres and cancer mortality, with mortality risk increasing

significantly for patients living more than 100 km away from the healthcare facility [4, 5].

These barriers are particularly pronounced in the context of palliative care, where the physical and emotional burden of travelling long distances may outweigh the perceived benefits of treatment. As a result, palliative patients may forgo radiotherapy in favour of remaining in a familiar and supportive environment [14–16]. However, evidence shows that radiotherapy plays an important role in palliative cancer care, providing symptom relief, preventing complications, and improving quality of life [16–20]. Providing the full radiotherapy procedure at the satellite unit ensures access to treatment for palliative patients. In line with the hypothesis that improved geographical access may reduce barriers to treatment initiation, descriptive data indicate a small increase in the proportion of patients initiating radiotherapy after a first consultation at the radiotherapy service following the implementation of the satellite unit in Fuerteventura. Specifically, this proportion rose from 74.5% in 2021 to 80% in 2023. Although this change might only be partially attributed to the satellite unit, it is consistent with improved access facilitating treatment initiation.

Regarding the focus on the healthcare system perspective used in our study, it is important to note that this perspective does not capture the full range of costs and benefits that may be relevant to patients, caregivers, and society as a whole. A survey conducted by the Spanish Association Against Cancer (AECC) among patients receiving radiotherapy treatment, revealed that 31% of radiotherapy patients in Spain reported income losses, which were especially pronounced among self-employed individuals who lose an average of €60 per day, compared to €27 per day for salaried worker. In addition, patient companions incur an estimated loss of €42 per treatment session [21]. International studies have also emphasised the economic burden associated with longer travelling for cancer patients. Zucca et al., 2011 reported that patients travelling over two hours or requiring temporary relocation for cancer care faced significantly higher rates of financial difficulty [22]. This burden has been found to be particularly unsustainable for self-employed individuals and those with caregiving responsibilities [23]. Beyond the impact of potential income or earning losses, maintaining work activity during cancer treatment has been reported to bring psychological benefits by offering a sense of control and normality [24, 25].

In addition to these limitations, a wide range of intangible benefits associated with reducing the distance to a radiotherapy centre are not accounted for in this study. These include improvements in patient autonomy, psychosocial well-being, and the ability to maintain caregiving and family roles [26–28]. Cancer often alters patients' perception of time, making them more aware of how they allocate and prioritise their daily activities [29]. In this context, travel time to receive treatment becomes a major barrier—one that extends beyond economic costs or employment disruption. Supporting this, the AECC survey found that the proportion of patients reporting "major difficulties" with radiotherapy doubled among those who had to relocate during treatment: while 13% of patients who did not change residence reported such difficulties, this figure rose to 28% among those who did [21]. Moreover, the study identified time spent travelling to radiotherapy sessions as the most commonly reported challenge—surpassing even financial concerns. Specifically, 44% of patients cited time as a significant barrier, followed by distance to the hospital (39%). Many respondents also emphasised the need to improve proximity to treatment centres as a key policy priority [21]. In the case of Fuerteventura, the journey to HUGCDN typically takes around 2.5 hours each way, representing a considerable time burden that adds to the broader disruption caused by having to travel for care.

Beyond the personal and social implications of long-distance travel for radiotherapy, there are also important environmental considerations that should be taken into account. Decentralising radiotherapy services has been argued to reduce the carbon footprint of healthcare delivery, as patient travel accounts for a large share—between 70% and 80%—of radiotherapy-related emissions [30]. A UK-based study estimated that reducing travel distances to a satellite centre could offset the carbon footprint of its construction within 5.6 to 10 years [31]. This study estimated a carbon footprint saving per patient of 0.0602 tCO_2e, assuming an average 11 km reduction in car travel distance. In the context of the satellite unit of Fuerteventura, where air travel is mostly used to access radiotherapy in Gran Canaria, the estimated emissions per trip are substantially higher. A single round-trip for a patient and caregiver might produce 0.514 tCO_2e. By eliminating the need for these journeys—replaced by a single daily trip from an oncologist treating over 15 patients—the satellite unit in the Canary Islands has the potential to generate substantial environmental benefits, beyond those estimated in Chuter, 2023 [31]. Moreover, because the Fuerteventura facility was installed within an existing building adapted for radiotherapy use, the environmental impact of its establishment might be offset even more rapidly.

In summary, if the additional benefits discussed—such as the potential clinical gains from improved access, the broader societal savings, the intangible effects on patients and caregivers, and the environmental impact—had been taken into account, the case for the satellite unit would have been strengthened. Further research should aim to incorporate these elements into a cost-effectiveness

framework, which would provide a more comprehensive assessment of the value generated by the satellite model.

Even without considering these broader impacts, our analysis provides valuable guidance for decision-makers considering the implementation of radiotherapy units in other remote areas currently lacking access to treatment. In particular, our analysis shows that, within the context of the Canary Islands, a satellite radiotherapy unit treating over 200 patients per year could achieve a comparable per-patient cost to that of a high-volume centre treating more than 2,500 patients annually—once transport and accommodation expenses are taken into account. When travel-related savings are excluded, the break-even point for equivalent direct healthcare costs across both sites is estimated at 271 patients per year. This suggests that the reimbursement of travel expenses by the health system is a key factor to consider when planning and evaluating decentralised services.

In addition, it is important to note that the validity of the cost-minimisation framework adopted in this study rests on the explicit exclusion of high-complexity radiotherapy treatments that are not available at the satellite unit. Approximately 25% of treatments delivered at the reference centre in Gran Canaria were therefore excluded to ensure that only equivalent treatments were compared. This distinction is essential for the correct interpretation of the economic results and to avoid extrapolating the findings beyond the scope of services provided at the satellite unit. Relatedly, we acknowledge the methodological challenges involved in isolating the costs associated with non-equivalent treatments in our analysis. As detailed in the Methods section, this was addressed through an activity-based costing approach that weighted procedures by their relative complexity, allowing us to approximate the share of total costs attributable to treatments comparable to those delivered at the satellite unit.

Beyond financial considerations, the literature identified in this study highlights additional advantages associated with proximity to radiotherapy centres—for patients, caregivers, and the environment—that should also inform service design. These benefits contribute to the fundamental goal of ensuring equitable access for all individuals within the population served by the healthcare system.

Conclusions

This study provides a comprehensive economic assessment of a satellite radiotherapy unit established in Fuerteventura to improve access to cancer care for residents of this island within the Canary Islands in Spain. Using a cost-minimisation approach, the analysis demonstrates that while the healthcare cost per patient receiving equivalent treatments at the satellite unit was higher than at the reference centre in its first full year of operation, this difference was partially offset by substantial reductions in travel-related costs. Moreover, the cost gap is expected to narrow as the unit becomes more established and patient volumes increase, with cost savings projected from 205 patients per year— a number already surpassed in 2024.

Beyond its economic implications, improved proximity to radiotherapy services may offer additional access-related benefits, as suggested by previous studies, including better treatment adherence and reduced patient burden. However, these potential advantages were not directly evaluated in this analysis and should be examined in future research.

In conclusion, decisions regarding the implementation of satellite radiotherapy units should be guided by robust cost data, anticipated patient volumes, and a comprehensive assessment of the potential impact on patients, families, and society as a whole—alongside a strong commitment to equitable access. The findings presented in this study offer valuable insights to inform similar evaluations in other geographically remote areas currently underserved by radiotherapy services.

Annex 1 Complexity levels assigned to treatments provided at HUGCDN

Level 1
3D-CRT + IGRT (1–10 fractions)
Vaginal brachytherapy (cylinder)
Single-session VMAT
Level 3
VMAT
VMAT + IGRT
SBRT
Chemotherapy
Hyperbaric chamber
Perioperative brachytherapy
Skin and lip brachytherapy
Endoluminal brachytherapy
Level 4
Radiosurgery (CyberKnife)
SBRT with breath-hold technique
SBRT with intrafraction monitoring (CALYPSO)
Craniospinal irradiation
Interstitial gynaecological brachytherapy
Prostate interstitial brachytherapy
Partial breast brachytherapy
Hyperthermia
Level 5
Paediatric radiotherapy with anaesthesia
Total body irradiation (TBI)
Intraoperative brachytherapy (sarcomas)

Abbreviations

3DCRT	3D conformal radiotherapy techniques
AECC	Spanish Association Against Cancer
HGF	General Hospital of Fuerteventura
HUGCDN	University Hospital of Gran Canaria Dr. Negrín

IORT	Intraoperative radiotherapy
SBRT	Stereotactic body radiotherapy
SCS	Servicio Canario de la Salud
SIPRE	Sistema de Información de Prestaciones
VMAT	Volumetric modulated arc therapy

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Author contributions
LVT, MEE, PBP, BGLV, and MLSB conceptualised the study, conducted data analysis and interpretation, and were involved in drafting and revising the manuscript. AMGA and MQF made substantial contributions to data acquisition, analysis, and interpretation, and participated in manuscript revisions. All authors read and approved the final version of the manuscript.

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Data availability
All data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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