BMJ Open

Health system costs of a breast cancer early diagnosis programme in a rural district of Rwanda: a retrospective, cross-sectional economic analysis

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ABSTRACT

Objectives This study aimed to quantify the health system cost of the first 2 years of a Breast Cancer Early Detection (BCED) programme in a rural district in Rwanda. We also aimed to estimate the cost of implementing the programme in other districts with different referral pathways and identify opportunities for enhanced cost efficiency.

Design Retrospective, cross-sectional analysis using time-driven activity-based costing, based on timed patient clinical encounters, retrospective patient data and unit costs of resources abstracted from administrative and finance records.

Setting The BCED programme focused on timely evaluation of individuals with breast symptoms. The study evaluated the health system cost of the BCED programme at seven health centres (HCs) in Burera district and Butaro Cancer Centre of Excellence (BCCOE) at Butaro District Hospital.

Outcome measures Health system costs per patient visit and cost per cancer diagnosed were quantified. Total start-up and recurring operational costs were also estimated, as well as health system costs of different scale-up adaptations in other districts.

Results One-time start-up costs were US$36 917, recurring operational costs were US$67 711 and clinical costs were US$14 824 over 2 years. Clinical breast examinations (CBE) at HCs cost US$3.27/visit. At BCCOE, CBE-only visits cost US$13.47/visit, CBE/ultrasound US$14.79/visit and CBE/ultrasound/biopsy/pathology US$147.81/visit. Overall, clinical cost per breast cancer diagnosed was US$1482. Clinical cost drivers were personnel at HCs (55%) and biopsy/pathology supplies at BCCOE (46%). In other districts, patients experience a longer breast evaluation pathway, adding about US$14.00/patient; this could be decreased if ultrasound services were decentralised.

Conclusion Clinical costs associated with BCED services at HCs were modest, similar to other general outpatient services. The BCED programme's start-up and operational costs were high but could be reduced by using local trainers and virtual mentorship. In other districts, decentralising ultrasound and/or biopsies to district hospitals could reduce costs.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The time-driven activity-based costing (TDABC) method attaches cost to specific programme activities and time per activity, which allows for precise costing of integrated patient care.
⇒ The TDABC method enabled identification of variability and inefficiencies across different facilities in the breast cancer early detection programme pathway.
⇒ The costing analysis relies on assumptions for cost estimations, for example, personnel and space availability time, and electricity consumption of laboratory versus non-laboratory spaces, etc.
⇒ Due to the timing of data collection, total clinical costs were estimated retrospectively using unit costs from 2015 to 2017, but average time per activity was estimated from clinical encounters observed in 2021.
⇒ There is limited generalisability of these specific findings to other countries as the programme was designed specifically following the referral system and community health insurance system in Rwanda.

INTRODUCTION

Breast cancer is the most prevalent cancer globally with 2.3 million women diagnosed and 685 000 deaths in 2020.[1] Breast cancer incidence and mortality are increasing disproportionately in low-income and middle-income countries (LMICs). Late-stage diagnosis is a major contributor to high breast cancer mortality in low-income countries in particular, where over 50% of breast cancers are diagnosed at advanced stage.[2–4] Identifying strategies to facilitate earlier diagnosis of breast cancer in low-income countries is a global public health priority.[5]

In low-income countries, women typically experience long delays between the onset of breast symptoms and their diagnosis with

breast cancer.[2] While some of this delay is due to patients seeking care at later stages of disease, it has been shown that ineffective and inefficient care within the health system contributes to this problem. Interventions to facilitate timely breast cancer diagnosis among symptomatic individuals ('early diagnosis programmes') are an essential first step in building capacity for early detection in low-resource settings[6–8] and can lay groundwork for subsequent population-based screening. Essential steps of early diagnosis have been described by the WHO and include: (1) public sensitisation to ensure that communities are aware of early signs and symptoms and treatability breast cancer and where to seek care, (2) accurate clinical evaluation and timely referral through training of first-line health professionals and (3) access to timely, quality and affordable diagnostics and treatment through improvement of referral processes.[8] Despite growing recognition of the need to build evidence-based early diagnosis programmes in LMICs, few early diagnosis interventions in LMICs have been described in the research literature.

Rwanda is a low-income country of 12.5 million people in East Africa. In Rwanda, about three-quarters of patients with breast cancer are diagnosed with stage III or IV disease[9] when breast cancer is either difficult or impossible to cure. Pace et al[10] found patients experienced a median of 15 months between the onset of breast symptoms and breast cancer diagnosis; experiencing either patient or system delays of >6 months increased the likelihood of being diagnosed with stage IV cancer, disease that had already metastasised outside the breast and regional lymph nodes. To facilitate early diagnosis in symptomatic patients, a breast cancer early detection (BCED) programme was developed and tested in a cluster randomised clinical trial in Burera District, a rural district in Rwanda's northern province where Rwanda's first public cancer facility, Butaro Cancer Centre of Excellence (BCCOE), is located. The programme combined community sensitisation with training of healthcare workers in performing clinical breast examination (CBE)[11] and breast ultrasound.[12] The programme significantly increased the breast health knowledge and skills of community health workers (CHWs) and nurses, who demonstrated appropriate clinical decision making with patients with breast concerns[11] and was associated with increased health facility visits by patients with breast symptoms.[13] Among individuals diagnosed with breast cancer who came from the geographic areas served by intervention health centres (HCs), 48% had early-stage cancer, vs 20% in control regions. Rwanda is now working to adapt and scale this intervention in other districts.[13]

Understanding the cost of this intervention is critical for Rwanda as it plans to expand BCED efforts and may also be valuable to other countries with under-resourced health systems considering prioritising breast cancer early diagnosis within routine healthcare services. Although some studies have estimated the costs of breast cancer screening in LMICs, there is limited literature on the cost of building early diagnosis capacity and providing early diagnosis services.[14] Using time-driven activity-based costing (TDABC) methodology, we sought to quantify the health system costs of the first 2 years of the BCED programme in Burera district including the clinical cost per patient evaluated, clinical cost per cancer diagnosed, one-time start-up costs and recurring operational costs. Using these data, we estimated the cost of other potential pathways of the BCED programme in other districts, and identified opportunities for enhanced cost efficiency as the programme is scaled.

No microcosting analysis of an existing programme has been performed for a BCED programme in sub-Saharan Africa. Our objective was to inform scale-up in Rwanda, guide prioritisation and planning of breast cancer early diagnosis programmes in other limited-resource settings and add to the limited body of existing literature on the cost of BCED in LMICs.

METHODS
The BCED programme in Burera district, Rwanda
The BCED programme was implemented by the non-governmental organisation Partners In Health (PIH) in collaboration with Rwanda's Ministry of Health. The programme consisted of health worker training, mentorship, adoption of structured clinical algorithms and establishment of weekly, dedicated breast clinics. It was implemented in the community, at primary healthcare centres in Butaro district, and at BCCOE, a cancer referral centre which is housed at Butaro District Hospital. The programme was evaluated in a two-phase cluster randomised controlled trial in Burera district HCs and BCCOE.[13] The first phase of the intervention started in April 2015 in seven randomly selected HCs, while phase two started in November 2015 in five additional HCs. The programme involved a 1 day training of Community Health Workers (CHWs) who were instructed in teaching communities about breast cancer signs, symptoms and treatability, and breast self-awareness. HC nurses received a 1-week training in CBE and management of breast concerns.[11] Finally, district hospital staff received a 7-week on-site training in diagnostic breast ultrasound led by four US-based radiologists.[12] The BCED programme was accessed through weekly breast clinics established at HCs. Patients with abnormal CBE were referred to BCCOE for further CBE with diagnostic breast ultrasound, core needle biopsy and pathology laboratory services including tissue diagnosis (H&E) and immunohistochemistry. At BCCOE, low-income patients also received support for transport, and starting in 2016, they received food and housing if they needed an overnight stay while awaiting biopsy services. To support clinical decision-making, simple clinical algorithms were developed for the HCs, and a trained nurse midwife provided regular in-person mentorship to each HC through weekly or bi-weekly visits to their breast clinics. Over the 2-year intervention, additional weeklong training sessions were held for new staff, and HC focal points received supplemental mentorship

through training visits to the BCCOE oncology clinic. Following the initial 7-week training, ultrasound trainees at BCCOE received 2-week long follow-up trainings as well as virtual mentorship from radiologists.[12]

Patient and public involvement

The BCED project was developed following observation of the prevalence of late-stage breast cancer diagnoses at BCCOE.[9] In a previous patient survey, patients described long diagnostic delays,[10] and in clinical encounters and patient support groups, patients voiced the need for interventions to facilitate earlier diagnoses, informing our research agenda. The importance of understanding programme costs has been voiced by government partners in Rwanda and led to our pursuit of this economic analysis.

Study design and data collection

We conducted a retrospective cross-sectional economic analysis of the BCED programme over two years from the health system perspective using TDABC.[15 16] Following the TDABC method, a process map was iteratively developed via direct observation and staff discussion to understand the BCED process and to identify resources such as personnel, location, equipment, drugs and indirect costs needed for BCED programme activities. To enhance feasibility of data collection, we focused our costing analysis on the seven HCs enrolled in the first phase of the BCED programme only.

From human resource records at the HCs and the referral centre, data on personnel salaries and working hours were obtained. Hospital finance records, annual budgets and expenditure reports were reviewed to obtain costs of purchasing equipment, consumables, medications, indirect costs and construction costs. At each health facility, 5–10 patient visits for breast healthcare were observed and timed in June–July 2021 in order to quantify the average duration of use of each resource in a patient visit. In addition to the clinical costs obtained using the TDABC method, one-time start-up costs (initial purchases and trainings) and recurring operational costs (recurring costs required to centrally administer and sustain the programme) were obtained from PIH financial records to calculate the total cost of the BCED programme. Although some start-up costs (such as initial trainings and materials) would be expected to yield use for more than 2 years, we chose to include the full cost in this analysis for transparency and to facilitate planning by other organisations.

During implementation of the BCED programme in 2015–2017, information on service utilisation and diagnoses was abstracted from medical records at HCs and BCCOE and compiled into MS Excel and MS Access databases. From these existing databases, we extracted data on patient visits at the seven study HCs and BCCOE, including the total number of patients seen, the dosage and frequency of prescribed medications, the number of patients referred to BCCOE and the number of patients that received ultrasound, biopsy and pathology services.

Costing analysis

Start-up costs such as initial training and purchases, and recurring operational costs such as ongoing mentorship, programme coordinator salaries and refresher training were calculated by summation of costs from 2015 to 2017 BCED expenditure reports. Clinical costs were grouped into six categories: personnel, location (equipment, space and electricity), consumables, drugs, machines and indirect costs (online supplemental appendix 1) and stratified into two levels: HC and BCCOE referral centre. Costing analysis for the six categories was conducted following the TDABC method as follows:

Personnel

Personnel costs include cost of all clinical and support staff directly involved in the BCED programme care cycle at both HC and BCCOE levels. This includes nurses, general practitioners, pathologists, laboratory staff, pharmacists, social workers, cashiers and data clerks. To obtain the cost of personnel, the capacity cost rate (CCR), defined as the cost of providing personnel per minute was multiplied by the probability-weighted time (PWT), defined as the estimated time allocated to a specific activity. The CCR and PWT were obtained using the formulae below:

$$\text{personnel CCR} = (\text{annual salary} + \text{fringe benefits}) \text{ US\$} / \text{annual availability time (minutes)}$$

$$\text{personnel PWT} = \text{observed activity time (minutes)} \times \text{probability of involvement}$$

Location

During the study period, the BCED clinics at HCs and BCCOE were held once a week, therefore, the cost of location was calculated with the assumption that space and equipment were available for 52 weeks, 1 day a week, 9 hours a day (online supplemental appendix 2). Purchase prices for equipment (including an ultrasound machine) and cost of construction per square metre were used to calculate the CCR of equipment and space, respectively, accounting for annual depreciation. For BCCOE, electricity costs for each room, which were estimated based on square footage, were added to the CCR of space. Based on the energy consumption of laboratory machines as reported by a previous study conducted at Butaro hospital,[17 18] it was assumed that laboratory spaces consumed 25% of the total annual electricity while the remaining 75% was consumed by non-laboratory spaces (online supplemental appendix 2). To obtain the total CCR of location, the sum of the CCR of space and equipment was obtained. The cost of each location was then obtained by multiplying the CCR of the location by the PWT spent in each location by the patient for non-laboratory spaces, as well as patient samples for laboratory spaces. For the laboratory space, the cost of laboratory machines was not included in the location cost and were

calculated separately as described below. The CCR of location at HCs did not include electricity. The PWT and CCR of location were obtained using the formulae below:

$$\text{location PWT} = \text{observed activity time}$$
$$\times \text{probability of involvement}$$

$$\text{space CCR} = \frac{\text{cost of construction } (\$/m^2) \times \text{total area of space } (m^2)/\text{Useful years (mins)}}{\text{annual availability of space (mins)}}$$

$$\text{equipment CCR } \$/\text{min} = \frac{\text{cost of equipment } (\$)/\text{Useful years (min)}}{\text{annual availability of equipment}}$$

Consumables and medications

Consumables included ultrasound gel, biopsy needles, pathology reagents, drugs used during the biopsy procedure, and other laboratory supplies. Medications included prescriptions for patients such as paracetamol, ibuprofen, tramadol and cloxacillin. Only consumables and medications consumed by at least 10% of patients based on observation and study data were included in the cost calculation (online supplemental appendix 2). The cost of consumables and medications was obtained by multiplying the cost per patient by the probability of consumption—the probability of a particular consumable or drug being used by a patient. The cost per patient was obtained using the formula below.

$$\text{cost of consumables (or medications)} = \text{unit cost } (\$)$$
$$\times \text{units per patient}$$

Indirect costs

Indirect costs included hospital costs that are not directly related to patient care such as cleaning services, office supplies, equipment maintenance, telecommunication, transportation fees and housing provided to the lowest income patient and other utilities such as water and generator fuel. The total indirect costs of the BCED programme from 2015 to 2017 were obtained by averaging the totals of indirect costs of 2 years. Since the BCED programme is an outpatient service, the indirect costs of the programme were assumed to be 10% of the total indirect costs (online supplemental appendix 2). This assumption was based on indirect cost calculations used for outpatient services in a similar TDABC study conducted at Butaro District Hospital by Odhiambo *et al.*[17] The indirect costs per patient visit were obtained using the formula below:

$$\text{indirect costs } (\$/\text{patient}) = \frac{0.1 \text{ (annual indirect costs)}}{\text{total number of outpatients}}$$

Laboratory machines

Due to the high purchase price of laboratory machines, they were not included in the cost of the laboratory space; their cost was obtained separately by multiplying CCR and PWT using the formulae below.

$$\text{machine CCR } (\$/\text{min}) = \frac{\text{cost of machine } (\text{US}\$)/\text{Useful years (mins)}}{\text{annual availability of machines (mins)}}$$

$$\text{machines PWT} = \text{observed activity time}$$
$$\times \text{probability of involvement}$$

Total cost per patient visit

The sum of the cost of personnel, location, drugs, consumables, machines and indirect costs was obtained to get the total clinical cost per patient visit.

Extrapolating the BCED programme costs to other districts

Based on the health system costs of the BCED programme in Burera district health facilities derived using TDABC, we estimated the cost of different potential pathways for the programme in other districts. Cancer evaluation in Burera District is different than it is in other Rwandan districts because BCCOE, the country's primary public cancer referral centre, is colocated with the district's public hospital and at the time of the study, Burera patients could be referred directly from their HC to BCCOE. In contrast, in order for services to be covered by Rwanda's national health insurance system, patients from districts other than Burera are required to go to from the HC to their local district hospital; from their district hospital they can be referred to BCCOE. To facilitate estimation of the cost of scale-up to other districts, we used costs estimated for BCCOE to estimate costs at a typical district hospital; this approach has face validity since BCCOE is based at a district hospital. We then calculated the health system cost of the BCED programme for patients requiring a district hospital visit in between HC and BCCOE visits (current situation) and for two potential adaptations: (1) patients require a district hospital visit but there is breast ultrasound capacity at their district hospital; (2) patients can be referred directly from their HC to BCCOE.

Summary of assumptions

The costing relied on several assumptions detailed in online supplemental appendix 2. Based on the Rwanda public servant's protocols, the working hours for personnel was assumed to be 9 hours per day for 5 days a week. Based on the BCED programme schedule, the location was assumed to be available for the BCED programme once a week for 9 hours a day. Based on other TDABC studies,[17 18] only consumable resources used by at least 10% of patients were used in the costing. Based on other TDABC studies conducted at Butaro District Hospital, it was assumed that laboratory spaces consumed 25% of the hospital electricity and the remaining 75% was distributed among non-laboratory spaces based on their square footage.[18] Based on the same Butaro District Hospital TDABC study, it was also assumed that outpatient patient services take up 10% of total indirect costs.[18]

RESULTS

Figure 1 illustrates the process map of the BCED programme. The process starts at the community level where CHWs share information about signs, symptoms and risk factors of breast cancer. Symptomatic patients visit HCs for CBE; and referral to BCCOE is made for those who need further advanced diagnostic evaluation such as ultrasound and biopsy.
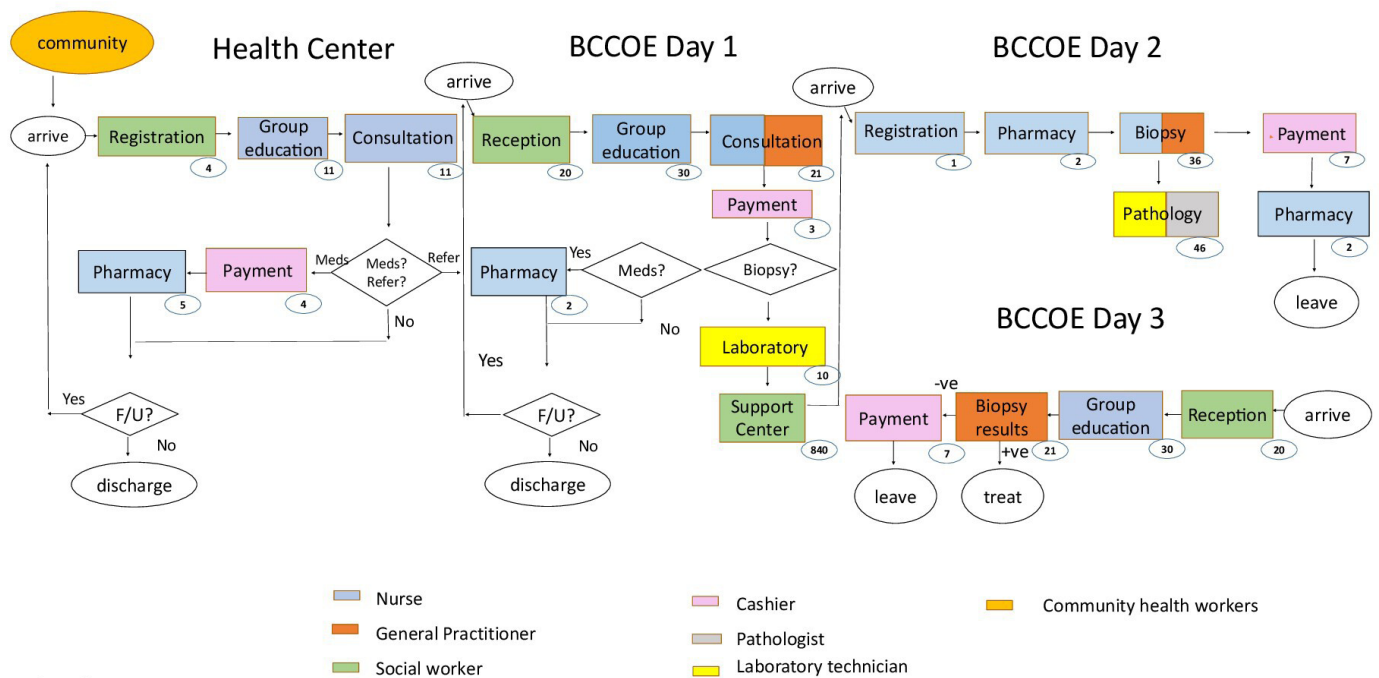
Figure 1 Process map for the Breast Cancer Early Detection Programme in Burera district. BCCOE, Butaro Cancer Centre of Excellence.

One-time start-up costs of the programme were US$36916.98. Start-up costs included the cost of purchasing equipment and training materials and conducting initial training of CHWs and health workers on CBE and breast ultrasound. Drivers of these costs included purchase of plane tickets for US-based ultrasound trainers and the initial training costs of health workers. Recurring operational costs during the first 2 years of the programme were a total of US$67710.75. This includes ongoing programme activities such as weekly in-person mentorship visits at HCs, CBE and ultrasound refresher trainings and programme coordination. Table 1 illustrates details of one-time start-up and recurring operational costs.

The clinical costs per patient visit are summarised in table 2. From April 2015 to April 2017, there were a total of 992 HC visits for breast concerns at the 7 initial HCs, and 210 referrals from these HCs to BCCOE for further evaluation. Among those seen at BCCOE, 130 individuals received CBE only, 15 received CBE and ultrasound, and 65 received CBE, ultrasound, biopsy and pathology. Ten patients were diagnosed with breast cancer. The clinical cost per average patient visit was US$3.27 at HC level. At BCCOE, the per-patient clinical cost varied according to the diagnostic evaluation done (table 2). A total of US$13.47 was the per-patient costs for CBE only, US$14.79 for both CBE and ultrasound and US$147.81 for CBE, ultrasound, biopsy and pathology services. Total clinical cost of services at the health facilities was US$14,824.44; that is US$18.14 per patient evaluated through the programme (817 patients evaluated) and US$1482.44 per

breast cancer diagnosed (10 breast cancers diagnosed) over the 2 years.

The allocation of clinical costs is detailed in figure 2. At the HC level, personnel costs were the highest cost driver at for 55% of the cost, while at referral centre level, the cost of consumables such as laboratory supplies accounted for the largest proportion of the cost at 46%. A more detailed breakdown of the clinical costs at each health facilities is summarised in online supplemental appendix 3 and 4 and the detailed data collection tool included in online supplemental appendix 1.

Estimated costs for various approaches to breast cancer early diagnosis services in districts outside Burera are shown in table 3. Provision of CBE and ultrasound at a district hospital and only biopsy and pathology services at the referral centre would cost US$147.92 per patient visit. If the district hospital step were eliminated entirely and patients could go from a HC to the referral hospital for repeat CBE, ultrasound, biopsy and pathology, this would cost about US$150.37 per patient visit. If CBE remained the only service available at the district hospital and all patients requiring ultrasound and/or biopsy and pathology had to go to the referral hospital, the cost would be US$164.55 per patient visit.

DISCUSSION

In this economic analysis of 2 years of a breast cancer early diagnosis programme implemented in a rural Rwandan district from 2015 to 2017, the average health system cost of clinical evaluation and diagnostic services at health

Table 1 Start-up and recurring operational costs of the BCED programme

	Year period and total cost (US$)	
	2015–2016	2016–2017
One-time start-up costs		
Purchases (folders, filling cabinets)	3008.94	0
Breast models for trainings*	4855.86	0
Computers and hardware	670.80	0
Initial CBE training of trainers	971.71	0
Nurses and CHWs CBE initial training	15023.68	0
Translation services fortraining materials	402.09	0
Stakeholders' initial meetings and retreat	2166.31	0
Initial ultrasound training (perdiems and meals for trainees)	1132.54	0
Plane tickets for four US-based trainers for initial ultrasound training	8685.06	0
Total	36916.98	0
Recurring operational costs		
Mentorship travel fees	2412.52	1556.93
Refresher CBE trainings (perdiems, travel, meals)	12818.50	–
Refresher ultrasound trainings (perdiems and meals for trainees)	–	828.76
Plane tickets for two US-based trainers for refresher ultrasound training	–	4003.54
Stakeholder meetings	–	1613.77
BCED mentors and programme coordinator salary	13944.34	13300.65
Hospital-based clinician consultant incentives	4503.36	3632.84
Telecommunication costs	5696.22	3399.30
S/total	39374.94	28335.81
Total	67710.75	

*Gaumard Breast Palpation Skills Trainer Torso.
BCED, Breast Cancer Early Detection; CBE, clinical breast examination; CHW, community health worker.

facilities was US$18.14 per patient evaluated, with individual visit costs varying from US$3.27 to US$147.81 depending on the services required. For comparison, yearly costs of managing patients with diabetes in Rwanda have been estimated to be about US$75–US$150 per patient per year depending on the nature of operational costs included.[19] Per-patient cervical cancer screening costs at health facilities were about US$26–US$37 in rural

Table 2 Health system costs of the Breast Cancer Early Detection programme in Burera district, Rwanda, April 2015–April 2017

	Average cost per patient visit	No of patient visits	Total cost
Health centre clinical costs*	US$3.27	992	US$3243.84
BCCOE clinical costs			
Clinical breast examinationonly	US$13.47	130	US$1751.10
Clinical breast examinationand ultrasound	US$14.79	15	US$221.85
Clinical breast examination, ultrasound, biopsy, pathology	US$147.81	65	US$9607.65
Total clinical costs		1202	US$14824.44
Total clinical costs per patient evaluated†			US$18.14
Total clinical costs per cancer diagnosed†			US$1482.44

*Health centre clinical costs include costs of personnel, location, drugs and indirect costs.
†n=817 unique patients evaluated and 10 breast cancers diagnosed in the study period.
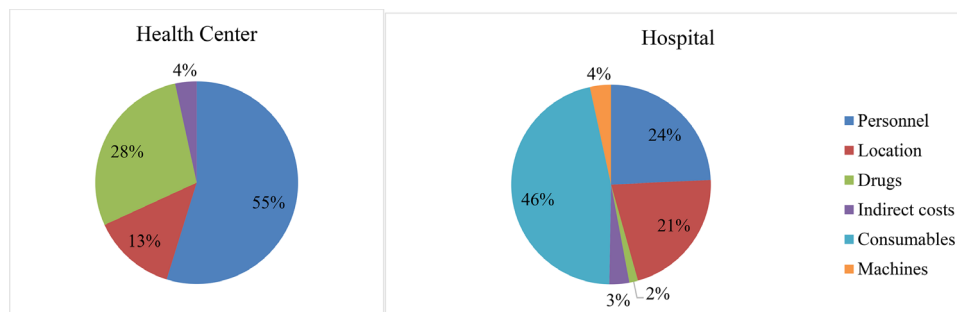BCCOE, Butaro Cancer Centre of Excellence.

Figure 2 Allocation of clinical care costs for the Breast Cancer Early Detection programme at the health centre and hospital level.

Kenya.[20] The cost per patient diagnosed with breast cancer over 2 years of the BCED programme was US$1482.

GLOBOCAN estimates that about 1237 women were diagnosed with breast cancer in 2020 in Rwanda (about 2474 over 2 years)[21] so if the programme were replicated unchanged around the country and all new cancers were diagnosed, the cost of clinical evaluation and diagnosis of those cases over 2 years would be about US$3 666 468. Particularly if cases are consistently diagnosed at an earlier stage as a result of early diagnosis programmes, such interventions may be cost-effective; further analyses will be important to determine this.

Cost-effectiveness will also increase with efforts to improve the efficiency of the intervention. This economic analysis reveals several opportunities for enhanced efficiency and provides lessons for programme scaleup. First, as would be expected, care delivery at HCs was far less expensive than care delivered at the hospital level, suggesting that strategic task-shifting or decentralisation of select services could enhance efficiency and reduce costs. Investing in skill-building at the HCs and developing systems to provide virtual guidance and decision support to HC clinicians could minimise unnecessary referrals to the hospital. If services such as sharing benign biopsy results were decentralised to HCs without compromising quality, this would reduce health system costs. In districts beyond Burera, patients are required to have a district hospital evaluation prior to obtaining a referral to BCCOE. At Rwanda's district hospitals, the only breast diagnostic service typically available is CBE. District hospital visits thus incur additional health system costs, but little value to patients. Decentralising diagnostic services such as breast ultrasound from the referral hospital level to the district hospital level may be particularly feasible and would allow referrals to BCCOE to be restricted to patients who require biopsy services or cancer treatment. Equally importantly, decentralisation of services would enhance patient convenience, decrease patients' out of pocket medical and non-medical costs, increase patients' ability to complete recommended evaluation, and potentially allow support services to be focused on the highest-risk patients. Decentralisation of preliminary diagnostics to secondary levels of care were recommended in a breast cancer management symposium in Rwanda.[22] However, decentralisation will require robust strategies for ongoing mentorship/supervision and quality assurance and the cost of these strategies must also be considered.

Second, our findings underscore that CBE and ultrasound are very inexpensive, while biopsies and pathology services are expensive due largely to the substantial cost of consumables such as biopsy needles and pathology reagents. Ultrasound can be an important tool for triage of palpable breast lesions, and by allowing benign appearing lesions to be observed without biopsy it may be cost saving for the health system and beneficial for patients. In cases where biopsy is needed, obtaining core needlebiopsy devices and reagents for biomarker assessment at a reduced cost, for instance through local

Table 3 Estimated per-visit clinical costs of different potential breast cancer early diagnosis pathways in other districts of Rwanda

Care delivery model	Health centre	District hospital	Referral hospital (BCCOE)	Cost per patient visit
Option 1—Health centres can refer patients directly to BCCOE	Clinical breast examination	–	Clinical breast examination +Ultrasound + biopsy +pathology	US$150.37
Option 2—Existing model requiring district hospital step	Clinical breast examination	Clinical breast examinationonly	Ultrasound+biopsy + pathology	US$164.55
Option 3—Existing model with ultrasound provision at district hospital level	Clinical breast examination	Clinical breast examination +ultrasound	Biopsy +pathology	US$147.92

BCCOE, Butaro Cancer Centre of Excellence.

or regional production of biopsy needles could have substantial public health impact.

Third, our costing analysis identified several inefficiencies in care at BCCOE that increased costs. The shortage of available clinicians trained in core needle biopsy led to limited biopsy slots at the oncology clinic, requiring most patients to make multiple visits (typically 3) for evaluation and diagnosis at BCCOE. Typically, patients' only opportunity for breast evaluation at BCCOE was the once-a-week consultation services on Mondays and biopsy services on Tuesdays. The lengthy process map increased costs to the health system in two ways. First, the cost of other non-clinical activities (registration, cashier, insurance verification), which accounted for 20.3% (online supplemental appendix 3) of the total cost per patient visit, were compounded over the three-visits. Second, it created a need for support services (eg, transport allowances, social work consultation and lodging) for vulnerable patients who had to travel long distances; these services were provided by the health system for patients at BCCOE starting in 2016. Of note, at other facilities, these would be costs borne by patients themselves. Therefore, besides the additional cost to the health system, requiring multiple visits has direct and indirect financial implications to the patients and could impact utilisation of BCED services and community perception of breast healthcare. Additionally, studies show that health system-factors, such as lengthy travel distances and high numbers of referrals needed before definitive diagnosis, may result in a more advanced stage of disease at diagnosis.[23 24]

In our programme, start-up and recurring operational costs were high, and substantially more than the cost of clinical care. Major drivers of start-up costs included the purchase of silicone breast models from the USA and engaging US-based trainers for intensive ultrasound training. Although these investments contributed to the success of the programme, opportunities exist for reducing these costs if the programme is implemented in other settings. These could include engaging locally based ultrasound trainers (potentially with virtual support and mentorship from remotely-based trainers who may have had opportunity for more specialised training in breast imaging) and using locally made breast models. The programme also included substantial recurring operational costs for in-person mentorship and refresher-trainings. Mentorship was highly valued by trainees and perceived to be an important contributor to the programme's success in building trainees' knowledge and skills,[11] but innovative lower-cost solutions such as virtual mentorship should be explored to facilitate expansion.

Our study has limitations. First, our costing methods relied on some assumptions to calculate the total cost of the BCED programme, as outlined in online supplemental appendix 2. In addition, to estimate the time used in clinical encounters in the 2015–2017 intervention, we observed care provided in 2021. However, these assumptions were minimised by verifying costs and time intervals through interviews with personnel involved in the

programme. Second, some of our calculated costs may have limited generalisability to other countries. Although we are familiar with care provided in other Rwandan districts and were able to extrapolate our findings to other districts in Rwanda, care systems differ in other countries and our data will have to be interpreted in that light. Third, we do not include medical and non-medical costs incurred by patients during their breast health-care journey. Understanding these costs will be critically important to understand the most efficient, effective and patient-centred models of breast cancer early diagnosis.

CONCLUSION

This study estimated health system costs of a breast cancer early diagnosis programme implemented in a rural Rwandan district over its first 2 years. Clinical costs were driven by personnel and pathologic diagnostics. Our findings will guide Rwandan policymakers as they scale up breast cancer early diagnosis efforts and may be useful for other LMICs seeking to establish similar programmes in their context.

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