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A comparative cost analysis of 25-fraction vs 5-fraction postoperative radiotherapy regimens for breast cancer

Dem Aliaj[a], Guido Schüpfer[b], Gabriela Studer[c]

[a] Faculty of Health Sciences and Medicine, University of Lucerne, Lucerne, Switzerland
[b] Institute for Anesthesia, Intensive Care Medicine, Pain Therapy and Rescue Medicine, Lucerne Cantonal Hospital (LUKS), Lucerne, Switzerland
[c] Institute for Radiation Oncology,Lucerne Canton Hospital (LUKS), Lucerne, Switzerland

Summary

PURPOSE: To compare the costs of 25-fraction vs 5-fraction postoperative radiotherapy regimens in breast cancer patients. Several clinical trials have confirmed at least comparable safety and efficacy of short hypofractionated partial and whole breast radiation regimens. This study was focused on providing detailed cost data and analysing the advantages or disadvantages of either treatment strategy for patients.

MATERIALS AND METHODS: Calculations were performed based on patient and infra-structure data collected from the department of radiation oncology at Lucerne Cantonal Hospital (LUKS) in Switzerland from 1 July to 31 December 2020. The process maps were created to identify resources used for each radiation therapy option, from initial consultation to treatment completion. Cost comparisons represent the viewpoints of the hospital, insurance coverages and societal costs.

To estimate hospital costs, time-driven activity-based costing was used, including equipment purchase and personnel costs. For insurers, estimates were based on the TARMED tariff system in Switzerland, which is used for billing ambulatory services and reflecting insurance coverage. The social cost was defined as productivity loss (e.g. absence from work) due to treatment appointments.

RESULTS: The 5-fraction regimens resulted in a total of 53% (972 CHF) lower hospital costs, including personnel and equipment resources, a 42% (3153 CHF) reduction of charges to insurers and a 62% (372 CHF) lower social burden in terms of productivity losses due to the patient's absence from work. The major findings from studies using 5-fraction regimens have shown a comparable result in terms of local control and treatment tolerance.

CONCLUSION: A5-fraction radiotherapy regimen in breast cancer patients results in a lower cost than a conventional 25-fraction regimen.

Introduction

Hypofractionated radiation treatment regimens (hRT) involve fewer radiation sessions by using higher doses per session. Hypofractionated radiation treatment is a treatment option for adjuvant radiation therapy in breast cancer patients. Compared to the historical use of hypofractionated regimens, modern technologies allow substantially better sparing of surrounding normal tissues [1]. In addition, radiobiological knowledge has substantially grown based on many clinical trials, empirical observations and radiobiological basic research [1]. In Switzerland, breast cancer is the most common tumour type in women, causing an average of around 1400 deaths per year between 2016 and 2020 [2, 3]. Normofractionated radiation therapy (e.g. 25 × 1.8 or 2.0 Gy per session) with 25 fractions delivered over 5–6 weeks ± boost dose application to the tumour bed was the traditional approach for postoperative breast cancer radiation therapy [4–7]. Postoperative whole breast irradiation (WBI) is a worldwide standard after breast-conserving tumour surgery to improve locoregional control. Over the last decades, ultra-hypofractionated accelerated partial-breast irradiation (APBI) using e.g. 5-fraction regimens has been prospectively studied for women with early-stage operated breast cancer. The major findings were a high and comparable local control, better treatment tolerance and substantially higher patient comfort compared to whole breast irradiation [8–13]. Similarly, several cohorts and two prospectively randomised trials (FAST and FAST-Forward) [14, 15] using a 5-fraction regimen (± sequential boost) have shown comparable results as for normofractionated radiation therapy also for postoperative whole breast irradiation (e.g. 5 × 5.2 or 5.4 Gy). These ultra-hypofractionated radiation therapy schedules offer the ability to complete whole or partial breast treatment in 1–2 weeks.

At the department of radiation oncology at Lucerne Cantonal Hospital (LUKS) in Switzerland, the clinical implementation of the 5-fraction accelerated partial-breast irradiation course started back in January 2017; the 5-fraction whole breast irradiation schedule according to the FAST-Forward trial was initiated in March 2020.

Despite robust evidence from prospective randomised controlled trials, accelerated partial-breast irradiation and the newer 5-fraction whole breast irradiation are not yet widely used outside the UK regions, due to nuances in local healthcare systems, reimbursement models and professional culture, to name but a few [16, 17].

Dem Aliaj
Faculty of Health Sciences and Medicine
University of Lucerne
CH-6002 Lucerne
dem-aliaj[at]hotmail.com

Meanwhile, the START B radiotherapy schedule using 15 fractions ± a boost dose application of 5–10 fractions [18, 19] is generally accepted as a new standard based on superior outcomes compared to normofractionation. In addition to the medical outcome analyses performed previously [5–15, 18], radiation therapy in breast cancer deserves interest for service providers and insurers due to the high costs associated with advanced technology which are burdensome for the hospitals. Nevertheless, the insurance reimbursements (for example, in the Swiss setting) often do not reflect the complexity of the radiation therapy investments [20].

To the best of our knowledge, a comparative economic study for different radiation therapy regimens for breast cancer patients in Switzerland has not been performed so far. The objective of the current analysis is, therefore, to compare a) the costs for the service provider, b) the charges to the insurers and c) the societal cost consequences of 5-fraction versus 25-fraction postoperative radiotherapy regimens for breast cancer.

Methods

Patient population

Two groups were selected for analysis at the radiation oncology department at Lucerne Cantonal Hospital, Switzerland: first, data from patients treated with the normofractionated whole breast irradiation schedule with 25 fractions (comparison group) as applied until 2015; second, data from patients who underwent the 5-fraction regimens (treatment group) in 1–2 weeks with accelerated partial-breast irradiation or whole breast irradiation (e.g. 5 × 5.2 or 5.4 Gy), initially started in 2017 and fully implemented as a treatment approach in 2020, respectively, to patients aged ≥50 years (accelerated partial-breast irradiation) and >18 years (whole breast irradiation). The approach we are reporting delivers a higher dose of radiation per fraction (treatment session) by Linac-based External Beam Radiotherapy over a shorter overall treatment course compared to conventional fractionation. The major findings from studies using 5-fraction regimens have shown a comparable result in terms of local control and treatment tolerance [8–13].

Patient data related to treatment plans were collected retrospectively via ARIA® software (Varian Medical Systems, Inc.). Follow-up data, staff consultations, infra-structural/processual data and time tracking were applied during the time horizon. All information was retrieved from 1 July to 31 December 2020.

Model structure and strategies

Time-driven activity-based costing as a bottom-up approach has previously been described by Kaplan and Porter and was defined as a suitable method for cost evaluations of delivering care, including the direct fixed costs of equipment (e.g. purchase price and maintenance) and direct variable costs of labour (e.g. wages and benefits) [21, 22]. The Swiss TARMED tariff was used to determine the charges to insurers for each service provided to patients by the hospital as the provider [23]. The societal cost was defined as a productivity loss due to the absence of patient's work. To estimate the societal cost, the patients' median monthly gross wages were extracted from the Federal Statistical Office (FSO) for the corresponding years 2015 and 2020. These data were used for female patients aged below 64 years with active professional status and full-time work, living in Switzerland. The estimates provided information on productivity loss due to missed work while attending scheduled treatments at the radiation oncology department. The wages were converted to per-minute values to calculate the cost of time spent in appointments [24] [table 4]. The economic evaluation was carried out according to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist [25].

To calculate the delivery costs of radiation therapy courses including labour and equipment, the detailed cost-accounting model was developed in Microsoft© Excel without the need for any additional statistical tools. To ensure fair time-independent comparisons, costs were discounted by 3% for all cost categories, consistent with recent Swiss economic evaluations [26, 27]. Our cost evaluation analysis includes the following steps:

1. *Define the care delivery value chain:* First, the care delivery value chain is specified to identify the principal activities involved in patient care required to deliver all services in the considered setting, from patient admission to treatment type completion.
2. *Structure the process map for each care activity:* The involvement of caregivers for each process was drawn chronologically and displayed. The process map function is shown as a flowchart and includes a detailed capacity – supplying resources required to patients, from initial consultation until treatment delivery (see appendix).
3. *Time estimates:* Measures the time spent by staff and the equipment allocations, estimated as average minutes devoted to each activity throughout the treatment cycle. Staff consultation, engagements from each specialty and observed clinical workflow details was performed to obtain time duration devoted by personnel instead of formal interviews. Note was made of potential outliers of individual factors for patient positioning and treatment activity, which was executed by radiation therapists. Treatment duration was manually recorded by a member of the study and approved by a therapist for a coded sample of 10 treatment plans with the 5-fraction regimen to validate and compare estimates with infra-structural/processual dataset of the 25-fraction regimen.
4. *Estimate the cost of supplying patient care:* The personnel and equipment costs capture both treatment techniques and allow comparisons between two applicable years: 25 fractions performed in 2015 and 5 fractions in 2020. For ethical reasons and to respect privacy, individual salaries of involved personnel was not permitted, but the average salary for the Canton of Lucerne for the relevant years, 2015 and 2020, according to professional title and years of experiences [28]was used for calculations. The equipment costs (e.g. CT scan and linear accelerator) include purchase prices (pre-tax), including VAT (8%) and depreciation for lifetime use of 12 years, and a markup for the yearly cost of maintenance.

5. *Estimate the capacity and calculate the capacity cost rate:* Capacity cost rate was defined as cost per radiation therapy regimen from the first to the last date and expressed in CHF for personnel and equipment. To calculate this, the annual capacity in minutes was estimated for the above resources. The personnel costs were calculated based on annual working days and average minutes spent for the active daily work, adjusted for holidays, weekends and nonpatient-related work (e.g. breaks and meetings). The capacity of equipment was determined based on their clinical availability per year and average minutes of workload per day. For each resource, the annual cost was divided by the annual capacity to determine the capacity cost rate.
6. *Estimate the total cost of care:* Lastly, for each activity from every process, the time estimate was multiplied by the capacity cost rate for all involved resources to calculate the costs. The sum of all activity costs plus the cost of any consumable materials allows for estimating the total cost of patient care in the two radiation therapy regimens, 5-fraction and 25-fraction.

25-fraction radiotherapy

In all patients, a multidisciplinary team made decisions on oncological treatment for newly diagnosed cases, including recommendations for postoperative radiation. Radiation therapy planning and CT simulation were performed postoperatively, and images were imported into the ARIA® radiation therapy planning system (RTPS). Then, radiation oncologists drew radiation therapy planning target volumes, which were then used by dosimetrists and physicians to define the treatment plan, checked by physicists, and finally approved by responsible staff physicians. Linear-based External Beam Radiotherapy delivered the irradiation dose. Lastly, patients were assigned to follow-up visits once a week.

5-fraction radiotherapy

The processing pathway for 5-fraction radiation therapy is similar as for conventional radiation therapy, but with higher daily treatment doses (ultra-hypofractionated) over a shorter duration time (5 workdays) with a total dose of 26–27 Gy. The treatment is delivered by the same linear accelerators using more than two tangential fields, either for whole breast irradiation or accelerated partial-breast irradiation, and deep inspiration breast holds (DIBH) were performed in patients with a left-sided tumour. The patients are assigned two doctor visits to evaluate any potential concerns during the treatment process.

Results

25-fraction schedule costs

Tables 1–4 present the results of cost comparisons between two treatment strategies across three domains: hospital costs (e.g. personnel and equipment), insurance expenditures and the economic burden of productivity losses.

Hospital cost

Tables 1–2 (panel A) show the cost breakdown attributed to the treatment processes including personnel and equipment. Table 1 (panel A) shows the total personnel cost for the 25-fraction regimens which resulted in 1153 CHF per case, and includes MD consultation, radiation oncologist visits, CT scanners, a dosimetrist plan, radiation therapy, medical physicist check and nurse counsel. The most expensive personnel-related activity was attributed to radiation oncology visits (412 CHF), representing 35% of the total cost, followed by the MD's clinical preparation.

Table 2 (panel A) shows the total equipment costs, which resulted in 684 CHF per case, including the CT scan and the linear accelerator (LINAC); the highest cost was for

Table 1:
Cost comparisons: Personnel cost per case. Panel A and B show how the hospital wage expenditure for personnel was distributed per course according to 25-fraction and 5-fraction schedules, and repetitive tasks.

Panel A. Personnel cost for 25-fraction regimen							
Map number	**Process**	**Number of repetitions**	**Time following care (min)**	**Number of personnel involved**	**Process cost (CHF/min)**	**Total cost (CHF)**	**Total cost (%)**
1	MD clinical preparation	5	45	1	1.22	274	23%
2	Radiation oncologist	5	40	1	2.06	412	35%
3	CT scanner	1	15	2	0.67	20	2%
4	Dosimetrist	1	45	1	0.72	32	3%
5	Radiation therapist	25	6.4	2	0.68	217	20%
6	Physicist check	25	6.4	1	0.97	155	13%
7	Nurse counsel	2	15	2	0.72	43	4%
Total						**1153**	**100%**
Panel B. Personnel cost for 5-fraction regimen							
Map number	**Process**	**Number of repetitions**	**Time following care (min)**	**Number of personnel involved**	**Process cost (CHF/min)**	**Total cost (CHF)**	**Total cost (%)**
1	MD clinical preparation	2	45	1	1.4	126	21%
2	Radiation oncologist	2	40	1	2.4	192	33%
3	CT scanner	1	15	2	0.8	24	4%
4	Dosimetrist	1	45	1	0.84	37	7%
5	Radiation therapist	5	11	2	0.79	86	15%
6	Physicist check	5	11	1	1.13	62	11%
7	Nurse counsel	2	15	2	0.84	50	9%
Total						**577**	**100%**

the linear accelerator (676 CHF), representing 99% of total equipment costs.

Insurance expenditures

This relates to the coverage of expenditures incurred by the provision of health services for each patient and recognised by the TARMED tariff with respective tax points, converted into Swiss francs accordingly. Table 3 (panel A) shows the collected tax points for the CT scan, the dosimetrist plan and radiation therapy from the first day until the last treatment. The total charges resulted in 7504 CHF.

Societal loss

Table 4 (panel A) describes the patient's path and includes doctor consultation, CT scan, check-in, waiting time, radiotherapy and nurse counselling. The total cost due to productivity loss resulted in 601 CHF, based on the gross average income per minute according to FOS data for patients aged between ≥50 years (accelerated partial-breast irradiation) and >18 years (whole breast irradiation) (41.00 CHF/h, in 2015) and estimates the time spent at the radiotherapy unit.

For this analysis, the societal cost included the *productivity loss* due to the patient's absence from work, which was measured according to the average time spent at the radiation oncology centre. The estimate of productivity losses follows the opportunity cost principle, i.e. losses are estimated as the cost of the time spent at the hospital, which provides implications of loss of workplace performance. The results of time spent at the care unit were multiplied by the number of appointment repetitions and multiplied by the gross wage of each patient group to show the potential impact of productivity loss to their employers.

5-fraction schedule costs

Hospital cost

Tables 1–2 (panel B) show the cost breakdown attributed to the treatment processes including personnel and equipment. Table 1 (panel B) shows that the total personnel cost per case for the 5-fraction regimens resulted in 577 CHF, and the process and activities are the same as for the 25-fraction regimen technique, although with fewer repetitive tasks (5 instead of 25 scheduled attendances). The most expensive activity was radiation oncology visits (192 CHF), representing 33% of the total cost. Table 2 (panel B) shows the total equipment cost, which resulted in 288 CHF, including the CT scan and the linear accelerator, the highest cost item (278 CHF) relating to the latter, representing 97% of the total.

Insurance expenditures

Table 3 (panel B) shows the collected taxpoints for the CT scan, the dosimetrist plan and radiation therapy. The hospital charges resulted in 4351 CHF per treatment course.

Table 2:
Cost evaluation comparison: Equipment cost per case. Panel A and B show the equipment cost for each treatment course, including maintenance for the CT scanner and the linear accelerator (LINAC), based on their cost per year, assuming a lifetime of 12 years and relying on repetitive processes required for radiation therapy regimen use.

Panel A. Equipment cost for 25-fraction regimen						
Map number	**Equipment**	**Number of repetitions**	**Duration of session (min)**	**Cost (CHF/min)**	**Total cost (CHF)**	**Total cost (%)**
2	CT scan simulation	1	15	0.56	8.4	1%
5	Accelerator machine	25	6.46	4.20	676	99%
Total					**684**	**100%**
Panel B. Equipment cost for 5-fraction regimen						
Map number	**Equipment**	**Number of repetitions**	**Duration of session (min)**	**Cost (CHF/min)**	**Total cost (CHF)**	**Total cost (%)**
2	CT scan simulation	1	15	0.65	9.7	3%
5	Accelerator machine	5	11.4	4.88	278	97%
Total					**288**	**100%**

Table 3:
Cost evaluation comparison: Insurance cost per case. Panel A and B show the insurance expenditures due to the reimbursement scheme pointing hospital's services according to the TARMED tariff mechanism.

Panel A. Insurance cost for the 25-fraction regimen						
Map number	**Process**	**Taxpoints**	**Number of repetitions**	**TARMED (CHF/Taxpoints)**	**Total cost (CHF)**	**Total cost (%)**
2	CT scan	320.58	1	0.72	230	3%
3	Dosimetrist	1338.68	1	0.72	964	13%
5	Rad. therapy	350.61	25	0.72	6310	84%
Total					**7504**	**100%**
Panel B. Insurance cost for 5-fraction regimen						
Map number	**Process**	**Taxpoints**	**Number of repetitions**	**TARMED (CHF/Taxpoints)**	**Total cost (CHF)**	**Total cost (%)**
2	CT scan	320.58	1	0.84	269	6%
3	Dosimetrist	1338.68	1	0.84	1124	26%
5	Rad. therapy	704.41	5	0.84	2958	68%
Total					**4351**	**100%**

Societal loss

Table 4 (panel B) describes the productivity losses due to the patient's path time following treatment schedules. The total cost of the productivity loss due to work absence resulted in 229 CHF. The highest cost element was time spent with doctor consultations (56 CHF), representing 25% of the total and is estimated based on the gross average income per hour according to FOS data for patients aged between ≥50 years (accelerated partial-breast irradiation) and >18 years (whole breast irradiation) (42.00 CHF/h, in 2020) and accounted for time spent at the radiotherapy unit.

Cost comparisons

Hospital cost

From the hospital perspective, a 5-fraction regimen resulted in 50% (576 CHF) lower personnel costs and a 58% (396 CHF) reduction in equipment expenses compared to a standard radiation therapy scheme. By implementing the new treatment technique, in total hospital costs (e.g. personnel + equipment) decreased by 53% (972 CHF) compared to the conventional 25-fraction per case. Furthermore, such a significant hospital cost wage decrease, by 576 CHF when implementing a 5-fraction regimen, due to the reductions of repetitive treatments and activities required by healthcare workers which later results in time savings and reduces hospital gross wage expenditures per treatment course. The radiation therapist (see figure S1 in the appendix) spent less time with the accelerator machine on the 25-fraction (6 minutes) than for the 5-fraction regimen (11 minutes), therefore the process for a fraction resulted in cost variations. However, both treatment regimens come as a package to treat patients in terms of treatment method and reimbursement tariffs.

Insurance expenditures

When comparing the payer's expenditures (insurance), the newer treatment technique of a 5-fraction regimen resulted in a decrease of 42% (3153 CHF). The decrease in insurers' spending from 7504 CHF to 4351 CHF was entirely related to the reduction in radiation therapy sessions, from 25 to 5 treatment fractions, and the associated taxpoint tariffs. However, a taxpoint-related surcharge was added for each radiation therapy session in the 5-fraction course because more treatment fields are required compared to the 25-fraction course.

Societal loss

The 5-fraction regimen reduced the economic burden by approximately 62% (372 CHF) compared to the 25-fraction regimen. This reduction was attributed to fewer missed workdays for patients assigned to the 5-fraction approach.

Discussion

This evidence provides a comprehensive analysis of the cost implications when evaluating treatment modalities for breast cancer.

The results show that the 5-fraction regimens resulted in a 53% lower hospital cost, including personnel and equipment resources, a 42% reduction in charges to insurers and a 62% lower social burden in terms of productivity losses due to the patient's absence from work.

The ultra-hypofractionated radiation therapy approach, compared with normo- or mild hypofractionated radiation therapy, offers the benefit to patients of a shorter treatment time as well as less immediate treatment side effects, besides less interference with the patient's normal life activity [29–31]. Porter et al. presented the goal for high-value care with money spent and meeting patients' needs which should be set mutually by physicians and board managers where all actors can benefit, including patients, payers and suppliers [32]. To understand the factual cost and manage a condition, it is crucial to have a methodology that allows cost evaluation not only on a departmental basis but also compares treatment strategies within departments. Researchers from Harvard Business School implemented a

Table 4:
Societal cost: Productivity loss due to the absence of work per case. These tables provide productivity losses in society due to the absence of patient's work due to treatment procedures for the time spent at the hospital. It was accounted for using monthly gross salary (h) according to FOS data respectively.

Panel A. Productivity loss for 25-fraction regimen						
Map number	**Process**	**Number of repetitions**	**Time following care (min)**	**Wage loss (CHF/min)**	**Total wage loss (CHF)**	**Total loss (%)**
1	Doctor consultation	5	40	0.65	130	22%
2	CT scan	1	15	0.65	10	2%
3.1	Check-in	25	5	0.65	82	13%
3.2	Waiting	25	15	0.65	243	40%
4	Rad. therapy	25	6	0.65	97	17%
5	Nurse counsel	2	30	0.65	39	7%
Total productivity loss					**601**	**100%**
Panel B. Productivity loss for 5-fraction regimen						
Map number	**Process**	**Number of repetitions**	**Time following care (min)**	**Wage loss (CHF/min)**	**Total wage loss (CHF)**	**Total loss (%)**
1	Doctor consultation	2	40	0.7	56	25%
2	CT scan	1	15	0.7	10.5	5%
3.1	Check-in	5	5	0.7	17.5	8%
3.2	Waiting	5	15	0.7	50.4	22%
4	Rad. therapy	5	15	0.7	52.5	22%
5	Nurse counsel	2	30	0.7	42	18%
Total productivity loss					**229**	**100%**

time-driven activity-based costing in several organisations, such as the Schön Klink in Germany and the MD Anderson Cancer Center in the US [22, 32]. The major advantage of using such a bottom-up costing approach for cost calculation in radiation therapy is that it yields more accurate costs and better cost structure; estimating the time in minutes attributed by personnel members and equipment used for breast cancer patients. The major cost drivers at the radiation therapy department at Lucerne Cantonal Hospital are wages, 1153 CHF for a 25-fraction regimen and 577 CHF for a 5-fraction regimen. The major time spent for patients at the radiation therapy department was related to doctor consultations, 3.3 hours for a 25-fraction regimen and 1.32 hours for a 5-fraction regimen, resulting in a productivity loss of 130 CHF and 56 CHF respectively. However, in a more global context, it was well recognised that the radiation therapy costs will depend on the types of technology available for use, i.e. protons are more costly than a photons beam, and the proportion of patients eligible to use [33].Other studies assessed the use of shortened fractionation radiation therapy approaches and compared them with conventional techniques; the results have shown the cost-effectiveness ratio advantages [34, 35], which are in line with our results.

Limitations

The main limitation of this study is its monocentric nature and specific economic evaluation according to the Swiss healthcare system. It represents practices at Lucerne Cantonal Hospital in the Canton of Lucerne, which may limit the generalisability of the findings to other regions.

Despite its advantages on micro-costing accounts, it is clear that the time-driven activity-based costing approach may face challenges when thinking of larger-scale applications other than the radio-oncology units, which may require, for example, more dedicated staff or software solutions that connect budgeting and treatment plan systems. The ultimate goal in cancer care is to define mixed costing models that balance treatment objectives, cost containment and clinical care.

The insurance expenditures decreased significantly by 42% (3153 CHF) when comparing 5-fraction with 25-fraction regimens. However, the TARMED mechanism was not entirely aligned with the full cycle of care coverages in hospital, because it did not address services in terms of collected taxpoints, e.g. some intermediate activities such as doctor visits and nurse consultations were missing to reflect on the TARMED platform for both treatment arms. Furthermore, productivity loss should address follow-up visits and treatment effectiveness after intervention (e.g. work productivity, activities), which was not addressed here due to a lack of available data.

Conclusion

In conclusion, this study shows that 5-fraction regimens were a less expensive strategy to treat patients than conventional 25-fraction regimens for a full care cycle, the hospital costs, the insurer's expenditures and societal costs. The clinical effectiveness of these two different radiation therapy schemes has been established by several RCTs [10–19]; the economic assessment of the two different radiation therapy schemes reveals that 5-fraction radiation schemes for breast cancer resulted in lower costs for the hospital as a provider and reduced charges for the insurers compared to the conventional 25-fraction regimens. Furthermore, patients treated with the 5-fraction regimen and who are actively working could return to work earlier.

Although 5-fraction radiation protocols generate less revenue, they create an opportunity to treat additional patients, which is crucial for maximising resource utilisation. Our study provides a foundation that can be used to extend analysis to other radiation therapy centres in Switzerland. Considering the increasingly high cost of oncology treatments, cost-benefit analyses are becoming more appreciated for provider investments and reimbursement policy decisions.

Data sharing statement

All data supporting the findings of this study are available within the article and the appendix.

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Potential competing interests
All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. No potential conflict of interest related to the content of this manuscript was disclosed.

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Appendix

The Cost Measurement Process

1. Define the care delivery value chain (CDVC): First, the CDVC was specified to identify the principal activities involved in patient care required to deliver all services in the considered setting, from patient admission to treatment type completion.
2. Develop process maps of each activity in patient care delivery: Identify the resources involved and any supplies used for the patient.

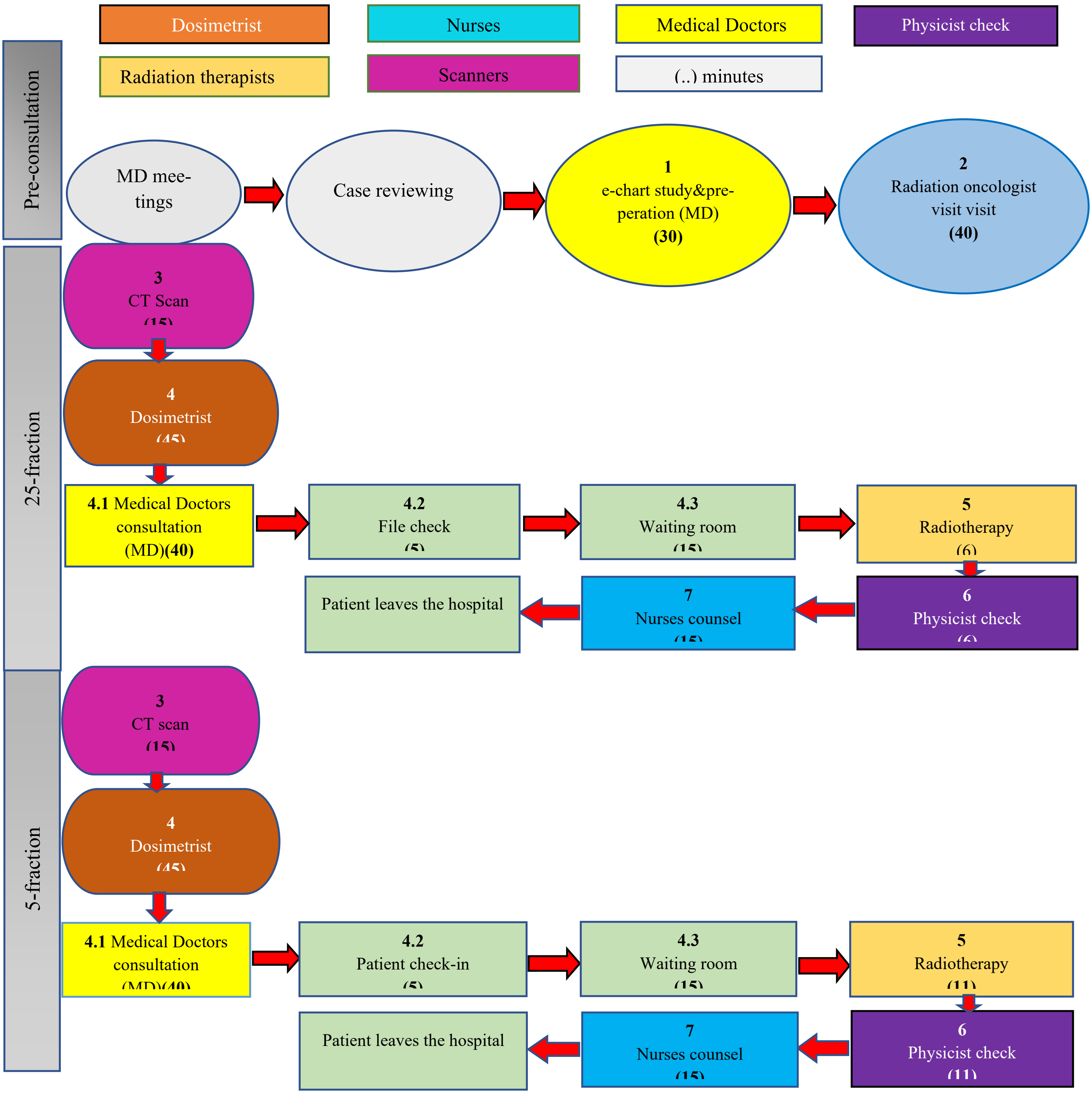
Dosimetrist
Nurses
Medical Doctors
Physicist check
Radiation therapists
Scanners
(..) minutes
Pre-consultation
MD mee-tings
Case reviewing
1
e-chart study&pre-peration (MD)
(30)
2
Radiation oncologist visit visit
(40)
25-fraction
3
CT Scan
4
Dosimetrist
4.1 Medical Doctors consultation (MD)(40)
4.2
File check
4.3
Waiting room
5
Radiotherapy
Patient leaves the hospital
7
Nurses counsel
6
Physicist check
5-fraction
3
CT scan
4
Dosimetrist
4.1 Medical Doctors consultation
4.2
Patient check-in
4.3
Waiting room
5
Radiotherapy
Patient leaves the hospital
7
Nurses counsel
6
Physicist check

FIGURE S1. Process map illustrates the patient's journey at each activity, with number indicating the sequence of steps and minutes spent on each activity (in brackets). Additionally, colours are used to indicate which specialist or department is responsible for each activity

3. Time estimates: Measures the time spent by staff and the equipment allocations, estimated as average minutes devoted to each activity throughout the treatment cycle and activity.
4. Estimate the cost of supplying care resources to each patient: In this step, we estimated the direct costs of each resource involved in caring for patients. The personnel and equipment costs capture both treatment techniques, which allow comparisons between two years: 25-fractions performed in 2015 and 5-fractions in 2020.
5. Estimate the capacity of each resource and calculate the capacity cost rate (CCR):

The CCR is defined as the cost per unit of time (e.g., per minute) for each resource. This is calculated by dividing the annual cost of personnel (e.g., salary, benefits) and similarly for equipment (eannual depreciation, maintenance) by its annual capacity in minutes.

First, estimate the time capacity for each available resource:

Personnel: Calculated based on the number of working days, hours per day, and adjusted for nonproductive time (e.g., breaks, training, meetings). For example, when an employee works 50 hours per week, their theoretical capacity is 3,000 minutes (50 hours x 60 minutes).

Equipment: Calculated based on the number of days the equipment is available per year and the hours it can be used each day, adjusted for downtime (e.g., maintenance). For example, when an accelerator machine is available for 249 days per year, and runs 9 hour per day, its annual theoretical capacity is 143,460 minutes (249 days x 9 hours x 60 minutes).

$$\boldsymbol{CCR\ (CHF/minute) = \frac{Total\ Annual\ Cost\ of\ the\ Resource}{Total\ Annual\ Capacity\ (in\ minutes)}}$$

This formula ensures that the cost of supplying resources is allocated based on the time each resource is actively used, which is a core principle of TDABC.

6. Calculate the total cost of patient care: In this final step, the project team calculates the total cost of treating a patient by multiplying the Capacity Cost Rate (CCR) for each resource used in each task by the time spent on that task. These individual task costs are then summed across all processes involved in the patient's complete cycle of care to determine the total cost of care for the patient.

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Table S1: Cost comparisons: Personnel cost per case.							
Panel A. Personnel cost for 25-fraction							
Map no	**Process**	**No Repetition**	**Time following care (Min)**	**Personnel involved (No)**	**Process cost (CHF/Min)**	**Total cost (CHF)**	**Total cost (%)**
1	MD clinical preparation	5	45	1	1.22	274	23
2	Radiation oncologist	5	40	1	2.06	412	35
3	CT-Scanner	1	15	2	0.67	20	2
4	Dosimetrist	1	45	1	0.72	32	3
5	Radiation therapist	25	6.4	2	0.68	217	20
6	Physicist check	25	6.4	1	0.97	155	13
7	Nurse counsel	2	15	2	0.72	43	4
Total						**1,153**	**100**
Panel B. Personnel cost for 5-fraction							
Map no	**Process**	**No repetition**	**Time following care (Min)**	**Personnel involved (No)**	**Process cost (CHF/Min)**	**Total cost (CHF)**	**Total cost (%)**
1	MD clinical preparation	2	45	1	1.4	126	21
2	Radiation oncologist	2	40	1	2.4	192	33
3	CT-Scanner	1	15	2	0.8	24	4
4	Dosimetrist	1	45	1	0.84	37	7
5	Radiation therapist	5	11	2	0.79	86	15
6	Physicist check	5	11	1	1.13	62	11
7	Nurse counsel	2	15	2	0.84	50	9
Total						**577**	**100**
Panels show how the hospital wage expenditure for personnel was distributed per course accordingly to 25-fraction and 5-fraction schedules, and repetitive tasks.							

Table S2. Cost evaluation comparison: Equipment cost per case.						
Panel A. Equipment cost for 25-fraction						
Map no	**Equipment**	**No repetition**	**Time session (Min)**	**Cost (CHF/Min)**	**Total cost (CHF)**	**Total cost (%)**
2	CT-Scan simulation	1	15	0.56	8.4	1
5	Accelerator machine	25	6.46	4.20	676	99
Total					**684**	**100**
Panel B. Equipment cost for 5-fraction						
Map no	**Equipment**	**No repetition**	**Time session (Min)**	**Cost (CHF/Min)**	**Total cost (CHF)**	**Total cost (%)**
2	CT-Scan simulation	1	15	0.65	9.7	3
5	Accelerator machine	5	11.4	4.88	278	97
Total					**288**	**100**
Panels show the equipment cost for each treatment course, including maintenance for CT-scan and the linear accelerator (LINAC), based on their cost per year, assuming a lifetime of 12 years and relying on repetitive processes required for RT regimens use.						

Table S3. Cost evaluation comparison: Insurance cost per case.						
Panel A. Insurance cost for 25-fraction						
Map no	**Process**	**Taxpoints**	**No repetition**	**TARMED (CHF/Taxpoints)**	**Total cost (CHF)**	**Total cost (%)**
2	CT scan	320.58	1	0.72	230	3
3	Dosimetrist	1,338.68	1	0.72	964	13
5	Rad. therapy	350.61	25	0.72	6,310	84
Total					**7,504**	**100**
Panel B. Insurance cost for 5-fraction						
Map no	**Process**	**Taxpoints**	**No repetition**	**TARMED (CHF/Taxpoints)**	**Total cost (CHF)**	**Total cost (%)**
2	CT-scan	320.58	1	0.84	269	6
3	Dosimetrist	1,338.68	1	0.84	1,124	26
5	Rad. therapy	704.41	5	0.84	2,958	68
Total					**4,351**	**100**
Panels show the insurance expenditures due to the reimbursement scheme pointing hospital's services according to the TARMED tariff mechanism.						

Table S4. Society cost: Productivity loss due to the absence of work per case.						
Panel A. Productivity loss for 25-fraction						
Map no	**Process**	**No repetition**	**Time following care (Min)**	**Wage loss (CHF/Min)**	**Total wage loss (CHF)**	**Total loss (%)**
1	Doctor consultation	5	40	0.65	130	22
2	CT-scan	1	15	0.65	10	2
3.1	Check-in	25	5	0.65	82	13
3.2	Waiting	25	15	0.65	243	40
4	Rad. therapy	25	6	0.65	97	17
5	Nurse counsel	2	30	0.65	39	7
Total productivity loss					**601**	**100**
Panel B. Productivity loss for 5-fraction						
Map no	**Process**	**No repetition**	**Time following care (Min)**	**Wage loss (CHF/Min)**	**Total wage loss (CHF)**	**Total loss (%)**
1	Doctor consultation	2	40	0.7	56	25
2	CT-scan	1	15	0.7	10.5	5
3.1	Check-in	5	5	0.7	17.5	8
3.2	Waiting	5	15	0.7	50.4	22
4	Rad. therapy	5	15	0.7	52.5	22
5	Nurse counsel	2	30	0.7	42	18
Total productivity loss					**229**	**100**
These tables provide productivity losses in society due to the absence of patient's work due to treatment procedures for the time spent at the hospital. It was accounted for monthly gross salary (h) according to FOS data respectively.						