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Original Article

National costs and resource requirements of external beam radiotherapy: A time-driven activity-based costing model from the ESTRO-HERO project

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ABSTRACT

Background: The Health Economics in Radiation Oncology (ESTRO-HERO) project aims to provide a knowledge base for health economics in European radiotherapy. A cost-accounting model, providing data on national resource requirements and costs of external beam radiotherapy (EBRT), was developed.

Materials and methods: Time-driven activity-based costing (TD-ABC) was applied from the healthcare provider perspective at national level. TD-ABC allocates resource costs to treatment courses through the activities performed, based on time estimates.

Results: The model is structured in three layers. The central layer, EBRT-Core, accounts for EBRT care-pathway activities and follows TD-ABC allocation principles. Activities supporting radiation oncology (RO) (RO-Support) and multidisciplinary oncology (Beyond-EBRT) follow standard allocation principles.

To demonstrate the model's capabilities, a dataset was constructed for the hypothetical country Europalia, based on published evidence on resources and treatments, whereas time estimates were expert opinions. Applying the TD-ABC model to this example, treatment delivery activities represent 68.4% of the costs; treatment preparation 31.6%. The cost per course shows large variation for different indications, techniques, and fractionation schedules, ranging between €838 and €7193. Resource utilization was estimated to be within the available capacity. Scenario analyses on changes in fractionation and treatment complexity are presented.

The ESTRO-HERO TD-ABC tool can model EBRT costs and resource requirements. While the Europalia example illustrates its potential, the results cannot be generalized nor used as a proxy for national evidence. Only real-world data, tailored to the specificities of individual countries, will support National Radiation Oncology Societies with investment planning and access to innovative radiotherapy.

The ESTRO-HERO project (Health Economics in Radiation Oncology) builds a knowledge base for health economics in European radiotherapy. It previously showed the inequity in available radiotherapy resources in Europe, demonstrated the gap between optimal and actual radiotherapy utilization, and highlighted the future needs [1–5]. Whereas adequate resource planning is essential to counter this growing needs and access divide, evidence-based guidance for radiotherapy provision across Europe is lacking. Most available guidelines for radiotherapy provision do not mirror the real needs, nor have they changed over the preceding ten years [3]. As such, current recommendations are not adapted to the needs of a European radiotherapy community facing rapidly evolving radiotherapy technologies, treatments and practice [3].

Besides, new radiotherapy approaches should be acceptable and affordable from a financial point of view before being introduced into clinical practice, hence made accessible to patients [6–8]. Defining the costs of new - and existing - interventions is a necessary first step of health economic appraisal supporting reimbursement decisions and policy-making [9]. Again, guidance is limited, with a paucity of available evidence on accurate radiotherapy resource costs [10].

The third work-package (WP3) of the ESTRO-HERO project focused on a model that can provide evidence on both the resource

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requirements and costs of actual and emerging practices and technical advances in external beam radiotherapy (EBRT). Using time-driven activity-based costing (TD-ABC), a cost-accounting model was developed to estimate the cost of EBRT service provision from the perspective of the healthcare providers at the national level in Europe. Ultimately, the aim is to enable radiotherapy professionals to assess not only the cost of different EBRT indications, treatments and techniques, but also the resource utilization and requirements at country level, all to inform reimbursement and resource planning decisions.

In this article, the ESTRO-HERO cost-accounting model is presented and applied to a hypothetical country Europalia, in view of subsequent implementation in the real-life setting. After describing the methodology, general structure and input data, the potential of this national cost-accounting model is illustrated through EBRT cost estimates, resource requirements and scenario analyses.

Material and methods

Activity-based costing (ABC) is a cost-accounting method developed to allocate indirect costs to products when resource consumption is not volume-driven [11]. It allocates resource costs to products through the activities performed in the production process. TD-ABC [12,13], an advanced form of ABC, uses time as the unique driver of resource utilization and allocates in one composite step [14]. Besides cost estimates, it also provides insight into resource requirements using two different allocation approaches: spending and usage [15]. The *spending approach* allocates all available resources to the products, even if not used at full capacity or, conversely, if resources would be insufficient based on time assumptions. The *usage approach* only accounts for resources actually used, i.e. it allocates the share of the resource costs actually involved in the production process. This approach therefore does not allocate the cost (revenue) of unused (overused) resources to the products [12,13].

In the context of radiotherapy, (TD-)ABC has been used to allocate personnel and capital resources to the radiotherapy courses. Computing the cost and resource impact of new radiotherapy indications, techniques or technologies is made possible by changing the resources used and/or their costs, or by modifying activities and their related activity times [16].

Whereas TD-ABC has been demonstrated a suitable cost-accounting method for EBRT costing from the institutional perspective [17], the current model was developed from the healthcare provider perspective at the national level. An initial survey amongst the national societies of radiation oncology (NS-RO) in Europe informed the project about the outputs such model should provide to support national policies. Interest was formulated in the cost of radiotherapy treatments and activities, the impact of changing practice (techniques, fractionation, quality assurance) and related resource needs. Considering these, the ESTRO-HERO WP3 task-force, composed of nine international experts in radiation oncology (MC, PD, CG, YL, JVL), epidemiology (JB) and health economics (JC, ND, LP), defined the general structure, data inputs and outputs of the model. Starting in September 2014, the model was developed in an iterative process informed by a systematic literature review [10]. Initial prototypes were developed in Excel/Visual Basic, once consolidated the ESTRO-HERO TD-ABC model was translated into a web-based platform (HTML/PHP/SQL, Invessel Ltd.). The project was carried out in close collaboration with the European NS-RO. An expert in TD-ABC outside the field of radiation oncology (SH) acted as a sounding board. The ESTRO-HERO TD-ABC platform was officially launched on 5 December 2017 during a NS-RO workshop.

Results

While the costing model is primarily developed to estimate the costs and resource requirements of EBRT, it is well-recognized that activities beyond the strict EBRT care-pathway are necessary to provide a complete, qualitative and safe radiation oncology (RO) programme. To account for these diverse levels, the model has been developed in three layers: EBRT-Core, RO-Support and Beyond-EBRT (Fig. 1a and b).

The *central layer* follows the TD-ABC methodology and provides insight into the EBRT-Core cost, based on the activities defined in the EBRT care-pathway, followed by the patient throughout his/her treatment course. It unfolds in three categories [13]:

1. *Resources:* personnel, equipment (with associated buildings) and consumables. Human and capital resources are clustered according to the task performed, e.g. Planning Task Group can be composed of different professionals performing planning; Imaging Equipment clusters different types of simulators;
2. *Treatments*: the number of EBRT courses per specific tumour site, intent, technique and fractionation scheme;
3. *Activities:* derived from the AAPM process map [18]. Originally developed for quality management, its structure has been adapted to fit the needs of this costing model: some sub-tasks of the AAPM process map were defined separately as optional steps in the care-pathway. Time estimates further allow characterization of six different techniques, capturing the variability of EBRT treatments and accounting for treatment complexity.

The *second layer* encompasses RO-supporting resources and activities *(RO-Support),* needed to provide a complete RO programme, e.g. quality managers, dosimetry equipment or implementation of new techniques. The *third layer* represents activities performed by RO personnel within the multidisciplinary oncology team, not related to EBRT as such *(Beyond-EBRT).* For both layers, the time invested by RO personnel is separated from the EBRT activities to estimate the cost of EBRT-Core versus RO-Support and Beyond-EBRT activities. In line with previous experiences, the cost of these two layers are assigned to courses using a 20/80 proportion, i.e. 20% of the costs are allocated using the total number of EBRT courses as denominator, 80% using the number of fractions [19,20].

The specific data input required for model application is defined for each category and illustrated with a data set constructed for the hypothetical country Europalia. Whereas for the resources distinction is made between data input necessary for EBRT-Core and RO-Support, treatments and activities only pertain to EBRT-Core.

*1. Resources (*Table 1*)*: numbers available in the country and their monetary value. Personnel comprises full-time equivalents (FTE) and annual salaries to the employer including social contributions. Following accounting rules, beyond annual holidays, only 80% of the theoretical time is available due to unavoidable pauses etc. [12,13]. Equipment cost accounts for depreciation and annual maintenance, including related bunker costs and re-allocated personnel costs for commissioning and annual machine quality control.

For Europalia, the number of resources is based on the median departments, equipment and staffing in Europe [4,5]; the monetary values on the Global Task Force on Radiotherapy for Cancer Control (GTFRCC) for high-income countries in 2013 [26].

2. Treatments (additional table, Appendix 1): EBRT courses delivered annually at national level, defined by tumour site and intent (29 curative indications, organized by primary tumour and five palliative indications organized by metastatic location), technique (single field radiotherapy, 2D radiotherapy (2D-RT), 3D-conformal radiotherapy (3D-CRT), intensity-modulated radiotherapy (IMRT),

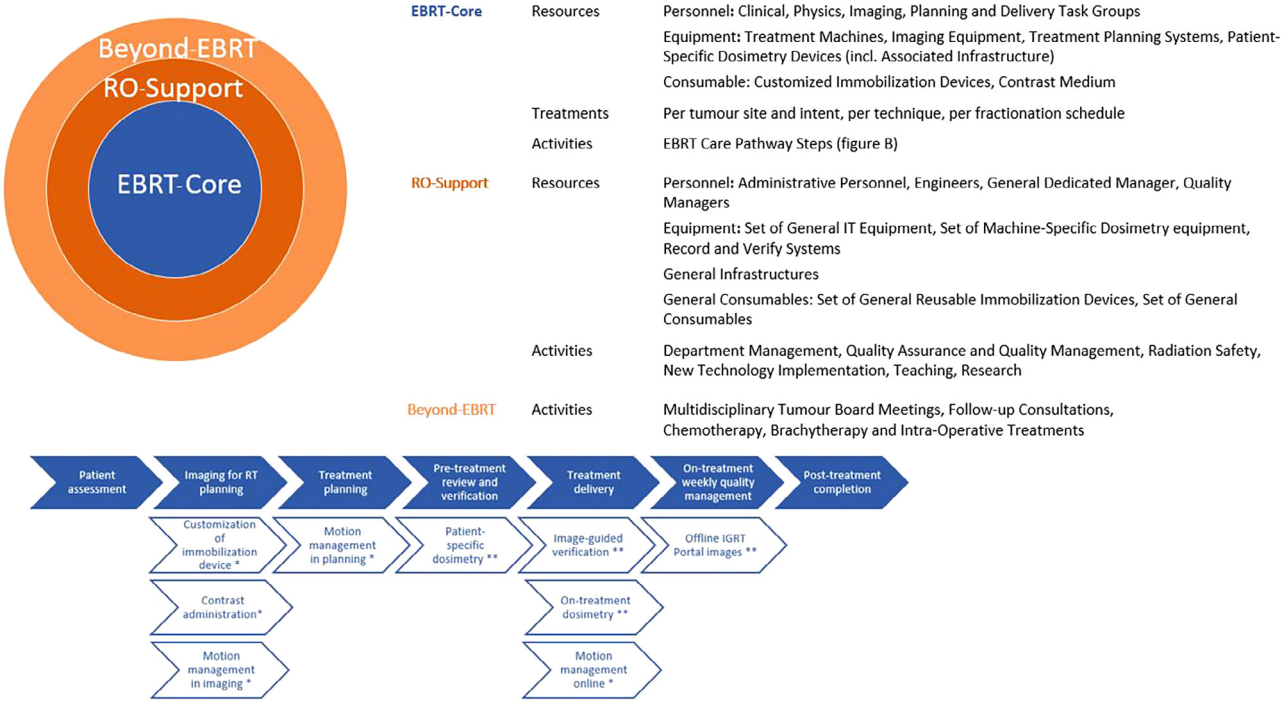


Fig. 1. ESTRO-HERO model structure. A. Inputs for each of the three layers constituting the model. B: EBRT Care-Pathway Steps. Legend: Full arrows: standard activities. Open arrows: optional activities; *optional activities defined per tumour site and intent, **optional activities defined based on the technique.

IMRT rotational, stereotactic techniques) and number of fractions delivered.

For Europalia, the actual number of EBRT courses is estimated at 49,233 per year, assuming an annual cancer incidence of 100,000 patients, on which the average optimal European radiotherapy utilization of 52.3% and the proportion and fractionation by tumour site and intent are applied, following the Collaboration for Cancer Outcomes, Research and Evaluation (CCORE) decision analytic model [1,22], then correcting for the average actual utilization proportion of 74.3% in Europe [1] and adding 25% retreatments [23]. Specifications of techniques and optional procedures were completed by HERO-WP3 experts, based on accepted practices.

3. Activities (additional table, Appendix 2): time (in minutes) of personnel involvement and equipment occupancy are defined per activity (EBRT-Core steps of the care-pathway and optional activities), differentiating for the six techniques. Equipment times are assumed to equate the related personnel time, i.e., the summed time of personnel using the equipment (if the tasks are performed sequentially), or the time of a referent task group (if tasks are performed in parallel).

For Europalia, personnel time for each EBRT-Core activity was estimated by the HERO-WP3 panel, informed by published evidence [24–26].

The share of time spent on RO-Support and Beyond-EBRT by various personnel task groups was defined for Europalia by the HERO-WP3 panel, based on accepted practices *(additional table, Appendix 3)*.

In the *spending approach*, reflecting the healthcare providers' actual expenses, the total cost of EBRT treatments was estimated at €118,198,046, with an additional €39,554,614 for RO-Support and €14,768,089 for Beyond-EBRT. Fig. 2 shows the proportional results breakdown for all constituting resources and/or activities. EBRT-Core preparatory activities represent 31.6%, treatment delivery activities 68.4%.

The *usage approach*, including only the costs incurred by the resources actually consumed, computes a total EBRT treatment cost of €95,613,816 or 80% of the spending cost as personnel and equipment are underutilized in this example (see next section).

Based on the assumptions taken in the model, a weighted average Europalia EBRT course costs €3518 (€2414 EBRT-Core) in the spending and €3045 (€1942 EBRT-Core) in the usage approach. However, as shown in Fig. 3a and b, considerable variation in cost occurs for different tumour sites, intents, and fractionation schedules (€838-€7193). For example, a curative intent prostate EBRT course costs €6092 on average, whereas a single fraction palliative bone EBRT course costs €1275; an average conventionally fractionated breast EBRT course amounts to €5543 compared to €3763 for a hypofractionated course. Similarly, there is also an impact of technical aspects, with e.g. average 3D-CRT treatments costing €3572, compared to €4191 for IMRT. Yet, this is predominantly related to a combination with other aspects, such as more frequent association of IMRT with image-guidance or motion management. As Fig. 3a and b illustrates, the cost impact of IMRT per se is limited, as the model does not account for different types (and costs) of equipment and the delivery times of IMRT were estimated similar to 3D-CRT.

With the *usage approach*, the actual resource utilization, all layers included, was estimated to be within the available capacity, ranging between 15% and 94%. For example, 94% of the available clinical task group time and 83% of the treatment machine time is used, compared to only 15% of the available time of patient-specific dosimetry equipment. In Appendix 4, the utilization distribution across all activities is shown.

The model also allows estimation of resource requirements for different scenarios, as illustrated in Fig. 4 (EBRT-Core only). Compared to the base case analysis where fractionation tends towards more protracted schedules (Appendix 1), the impact of implementing hypofractionation for lung and prostate irradiation and extreme hypofractionation for breast treatments is shown. The pressure on the treatment delivery personnel decreases by 2%, 9% and 16% for the respective scenarios, 27% all combined; the impact on other task groups is minor. For equipment, only the treatment

Table 1
Resource input parameters for EBRT-Core and RO-Support.

	Resources							Data source
	Personnel[1]	FTE	Annual salary	Paid hours/day	Worked hours/day[2]	Annual holidays		
EBRT-Core	Clinical task group	236	€ 171,360	8	6.4	28		Lievens 2014
	Physics task group	116	€ 92,383	8	6.4	28		Atun 2015
	Imaging task group	68	€ 48,807	8	6.4	28		
	Planning task group	116	€ 76,797	8	6.4	28		
	Physics staff	*33*	*€ 92,383*	*8*	*6.4*	*28*		
	Dosimetrist staff	*83*	*€ 70,600*	*8*	*6.4*	*28*		
	Delivery task group	610	€ 48,807	8	6.4	28		
RO-Support	Administrative personnel	118	€ 48,807	8	6.4	28		Expert estimates[3]
	Engineers	59	€ 70,600	8	6.4	28		
	Dedicated general Manager	45	€ 70,600	8	6.4	28		
	Quality Managers	45	€ 48,807	8	6.4	28		
	Equipment and associated infrastructure	Units	Purchase price	Maintenance contract[4]	Lifetime[4]	Annual quality control time/unit[4]	Commissioning time/unit[5]	
	Departments	45						Grau 2014
EBRT-Core	Treatment machines	118	€ 1,956,278	10%	12 years	15 days	30 days	Grau 2014,
	Cobalt	*3*	*€ 500,000*	*10%*	*20 years*			Atun 2015
	Linac	*111*	*€ 1,976,043*	*10%*	*12 years*			
	Dedicated Stereotactic Unit	*4*	*€ 2,500,000*	*10%*	*12 years*			
	Associated bunkers	*118*	*€ 482,115*	*2%*	*30 years*			
	Imaging equipment	59	€ 347,464	10%	12 years	5 days	5 days	
	Standard Simulator without CBCT	*0*	*0*	*0*	*0*			
	Simulator with CBCT	*0*	*0*	*0*	*0*			
	CT Simulator	*59*	*€ 347,464*	*10%*	*12 years*	*5 days*	*5 days*	
	PET Scanner dedicated for radiotherapy	*0*	*0*	*0*	*0*			
	Associated bunkers	*59*	*€ 378,412*	*2%*	*30 years*			
	Treatment planning systems	45	€ 231,076	10%	5 years	6 days	20 days	
	Associated planning room	*45*	*€ 378,412*	*2%*	*30 years*			
	Patient-specific dosimetry devices	45	€ 10,000	10%	5 years	2 days	3 days	
RO-Support	General infrastructure	45	€ 1,504,470	2%	30 years			Atun 2015
	Set of general IT equipment	45	€ 100,000	10%	5 years			Expert estimates[6]
	Set of machine-specific dosimetry equipment	45	€ 10,000	10%	5 years			
	Record & verify systems	45	€ 110,441	10%	5 years	3 days	10 days	
	General consumables	Units	Purchase price	Maintenance contract	Lifetime			
EBRT-Core	Customized immobilization devices		€ 50	na	na			Expert estimates
	Contrast medium (per unit)		€ 44	na	na			
RO-Support	Set of general consumables	45	€ 10,000	0%	1 year			Expert estimates[7]
	Set of general reusable immobilization devices[8]	177	€ 20,000	0%	5 years			

Abbreviations
FTE: full-time equivalent, EBRT: external beam radiotherapy, RO: radiation oncology, CT: computer tomography, CBCT: cone-beam CT, PET: positron emission tomography, RT: radiotherapy, IT: information technology.

[1] Personnel performing similar tasks are grouped together, their average weighted cost is applied. Resources outside the care-pathway are accounted for in RO-Support.

[2] Available time of 80% of the theoretical paid time accounts for unavoidable pauses etc.

[3] Expert estimates for RO-Support personnel: 1 FTE administration/treatment machine, 0.5 FTE engineer/treatment machine, 1 FTE manager/department, 0.25 FTE quality manager/treatment machine.

[4] In the annual maintenance contract, the energy consumption is assumed to be included. The purchase cost is depreciated over the equipment lifetime.

[5] Commissioning represents the cumulated time spend by the physics task group on initial commissioning, discounted over equipment lifetime. In addition, the annual number of days dedicated on machine-related quality control is displayed. Required training time of other task groups to use the equipment is foreseen as well.

[6] Expert estimates for RO-support equipment: 1 unit or set per department.

[7] Expert estimates for RO-support consumables: 1 set of general consumables/department; 1 set of general immobilization devices/imaging and treatment devices.

[8] Set of general immobilization devices: although these are not consumables per se, they have been categorized here due to the fact that replacement is often performed in function of the needs, instead of a formal investment.

machine requirements are impacted (Fig. 4a). As shown in Fig. 4b, the increased use of optional steps will again mostly impact the treatment delivery task groups and machines, as they are most involved. For example, applying daily IGRT (image-guided radiotherapy) to all 3D-CRT and IMRT (rotational) treatments, compared to the mix at base case, translates into 12% higher personnel requirements; motion management for all curative breast and lung treatments, in 7%.

Discussion

In times of budget scarcity, increasing attention is paid to economic evidence. While literature data on actual EBRT costs and on the financial impact of different radiotherapy innovations remain scarce [10], the European NS-RO reported that this type of information is crucial when negotiating for optimal access to and reimbursement of radiotherapy. To help closing this evidence gap,

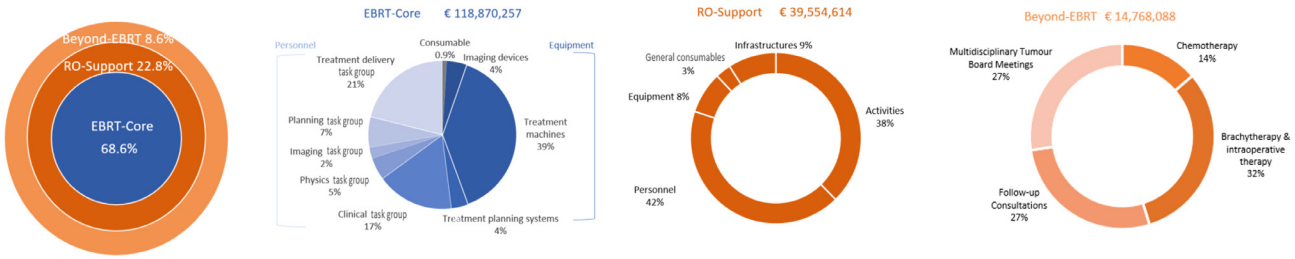
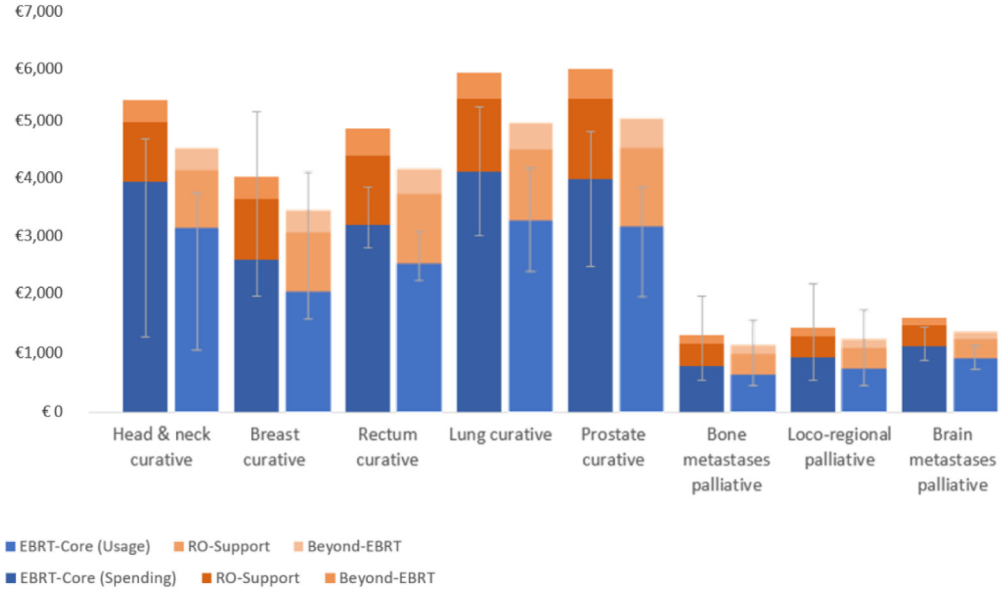


Fig. 2. Proportional costs of EBRT-Core activities, RO-Support and Beyond-EBRT (spending approach). Legend: The total cost of EBRT treatments is estimated at €118,198,046, with an additional €39,554,614 for RO-Support and €14,768,089 for Beyond-EBRT', it relates to 100,000 cancer patients which translates in 49,233 EBRT treatment courses per year.

A. Average cost of most frequent EBRT indications, by tumour type and intent.



B. Average cost of various curative indications, impact of technique and fractionation schedule.

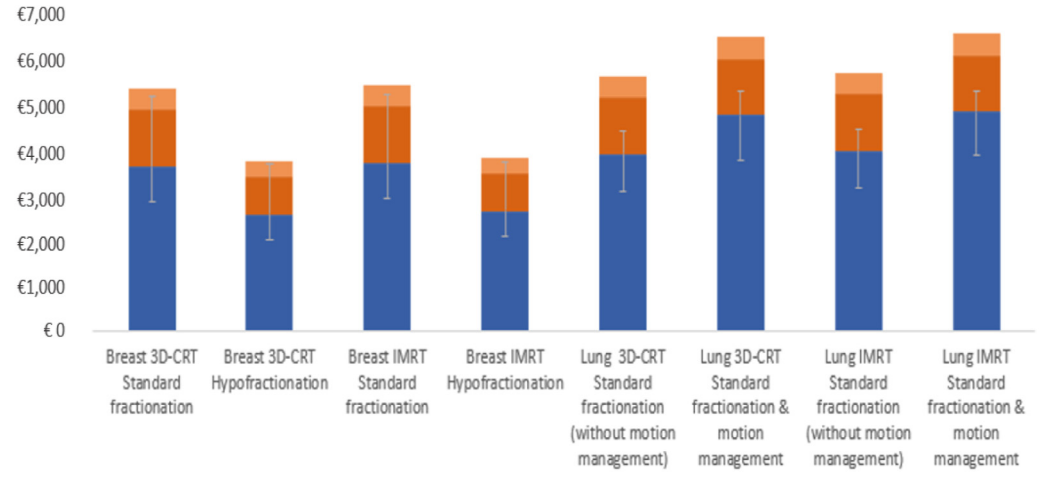


Fig. 3. Average Europalia EBRT cost per treatment, with the breakdown per layer. Legend: Fractionation schedules: standard (≥25 fractions), hypofractionation (11–24 fractions). The error bars relate only to the EBRT-Core costs, they show the minimum and maximum treatment cost of these tumour sites, intents and techniques, to which the RO-Support and Beyond-EBRT should be added. *Abbreviations:* EBRT: external beam radiotherapy, RO: radiation oncology, 3D-CRT: 3D-conformal radiotherapy, IMRT: intensity-modulated radiotherapy.

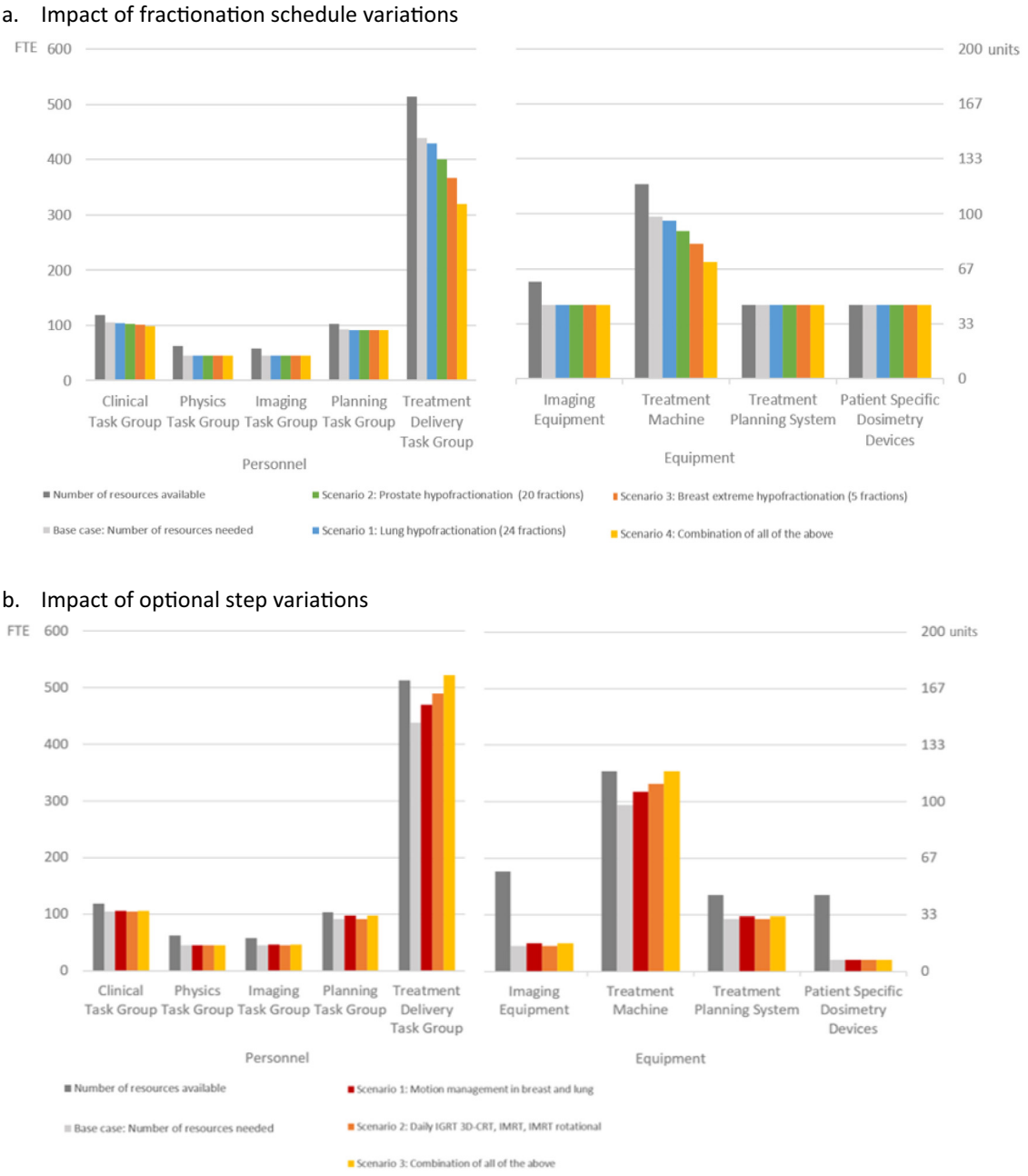


Fig. 4. Impact of simulated changes on resource needs for EBRT-Core, compared to available resources. Legend: The number of resources available displays the Europalia inputs; the base case shows the results of the usage approach for EBRT (excluding for RO Support and Non-EBRT activities). As mentioned in the table in Appendix 1, for fractionation, the base case assumes a mixture of hypofractionation and standard fractionation for breast (99.4%, respectively 0.6%) and for prostate (15.2%, respectively 84.8%), whereas lung only accounts for standard fractionation. For optional steps, the base case assumes a proportional use of motion management for curative breast cases of 50% during imaging, 12% for planning and 30% during treatment delivery (extra workload is required only for treatment with respiratory-gating and not for breath-hold); and res. 100%, 100% and 25% for curative lung courses. The use of IGRT is assumed to be 16% for first fraction, whereas res. 42% of the courses have 42% weekly or daily IGRT. Scenarios both on the fractionation schedules and optional steps are simulated to provide insight on the impact of practice change. In figure A, the impact of fractionation is simulated using hypofractionated schedules for all lung and prostate courses and extreme hypofractionated for breast courses. The scenarios for lung, prostate and breast locations have been computed using the following techniques; lung: 50% 3D-CRT, 25% IMRT and 25% IMRT rotational, prostate: 50% IMRT and 50% IMRT rotational, breast: 40% 3D-CRT, 30% IMRT and 30% IMRT rotational. In figure B, the impact of increased use of optional steps is simulated by assuming a 100% use of motion management for breast and lung cases in planning, imaging and treatment delivery and a utilization of daily IGRT for all 3D-CRT, IMRT and rotational IMRT. *Abbreviations:* FTE: full-time equivalent, IGRT: image-guided radiotherapy, 3D-CRT: 3D conformal radiotherapy, IMRT: intensity-modulated radiotherapy.

a TD-ABC model for EBRT, suitable for national implementation and available as a web-based tool, has been developed by ESTRO-HERO. TD-ABC provides a two-fold advantage: not only does it allow tracking costs more accurately at the activity and course level, but it also provides insight into resource utilization [12,13].

The presented TD-ABC model is the first developed with the specific aim to generate real-life national radiotherapy cost data to support population-level policy, which is national in most European countries [3]. Previous TD-ABC studies in the context of radiotherapy were performed either with real-life departmental data [17,19,20,27–29] or were modelling theoretical inputs [21,30,31]. The former has the disadvantage of providing centre-specific information, which may not be representative nation-wide; the latter provides hypothetical evidence that still necessitates a reality

check. That theoretical data can be extremely powerful to raise awareness and initiate policy debates, was demonstrated by the GTFRCC, which modelled global radiotherapy costs by income region [26]. It may be unexpected that the computed GTFRCC treatment costs were about 16% higher than ours (US$5368 or €4089, in 2013), while we used the same resource cost inputs [21,30]. One of the reasons is the treatment mix they modelled, which was slightly more complex and fractionated than ours. Yet, the single most important factor explaining the difference is their longer treatment timeslots, ranging between 12 and 18 minutes, compared to 10–12 minutes in our analysis. It is well-recognized that treatment-delivery time, by fraction or for the total treatment, dominates radiotherapy costs [20,32]. This illustrates how important it is to understand the structure and inputs of a costing model, in order to interpret the results.

The methodology applied is also critical. It is for instance difficult to relate costs computed with TD-ABC to costs derived from micro-costing, another conventional cost-accounting method, which solely focuses on resources consumed and their unit costs [33]. Micro-costing can be regarded as a usage approach. To date, published comprehensive TD-ABC EBRT cost studies have mainly explored the spending approach, which, as demonstrated for Europalia, generates higher costs. Indeed, by limiting the costs to actual utilization, a usage approach excludes the cost of idle resources. In radiation oncology, with a predominance of semi-fixed resource costs [34] and the need for some degree of over-capacity to accommodate variable patient influx while avoiding waiting times which may negatively impact outcome, the choice between usage and spending is not trivial. In contrast to what is commonly accepted for decision-making in accountancy [35], as this cost of over-capacity is unavoidable, we would dare to advocate for a spending approach to compute radiotherapy costs. A dual approach as offered in our TD-ABC model, however, provides the best of both worlds. The additional insight into resource utilization through the usage approach can estimate the required number of resources to serve a certain patient population, or, inversely, forecast how many treatments can be delivered by one machine or professional. This asset can be used to support radiotherapy planning, as nowadays guidelines fall short of reliable evidence on required resources in a continuously changing radiation oncology landscape [3,36].

The usage approach of our example, hypothetical yet based on average data collected at European country level, results in resource utilization at the lower bound of the QUARTS recommendations for personnel (209, 424 and 401 courses annually per radiation oncologist, medical physicist res. treatment machine, versus 200–250, 450–500 res. 400–450 recommended by QUARTS) [3,36]. This is not surprising as QUARTS recommendations are based on standards in force more than 15 years ago, whereas radiotherapy technology and practice have evolved tremendously in the same time span. Increasing radiotherapy complexity has resulted in intensified yet variable personnel workload, calling for recommendations considering treatment fractionation and complexity instead of patient numbers. One specific example is how the required number of radiation therapists (RTTs) typically remains linked to the number of machines, hence disregarding actual workload and participation in other functions [3]. Resource requirements reflecting actual practice can be supported by TD-ABC.

TD-ABC in a national context may underestimate the actual resource requirements and costs, for two reasons: lack of geographical spread and lack of hospital overhead. First, our model assumes extreme centralization, with decentralized departmental needs being only partly accounted for (e.g. minimum resource sets per department). The slight over-capacity observed in our modelled example can be expected to increase with increasing number of treatment sites, as each will need some slack to face peaks of patient influx. Economies of scale have been well-described to impact EBRT costs, larger departments resulting in lower costs [17,30,37]. Our model pushes this principle to the extreme. Second, it captures overhead directly related to radiotherapy and oncology services but fails to account for hospital overhead. In a real-world department, some of the costs borne are inherent to being embedded in a hospital structure, think general hospital management, accounting department, IT support, hygiene department, catering or maintenance of the hospital building. Such resources and services will all in some way be copaid by the clinical departments. The definitions of these overheads in costing models have been highly variable, hence insufficient data exist to substantiate the amount of hospital overhead to allocate [17,20,30,38]. If this is already an issue for costing exercises in departments, it evidently becomes even more complicated in a country-based model. It is expected that applying the model in real-life to both the national and departmental level, and benchmarking the results, will help to shed light on the financial impact of geographical spread and hospital overhead.

Other potential limitations should be borne in mind. While equipment variability is accounted for upfront by calculating its weighted average cost, the cost per minute is thereafter applied uniformly across technologies. Hence, the impact of using specific equipment for specific techniques cannot be analysed in the model. Moreover, this Europalia example defined the activity time estimates per technique, not for specific tumour sites or indications – although the model allows for this type of granularity in data input – again amalgamating the results to some extent. Finally, while we are confident that the spending costs give a good reflection of what would be observed in reality using similar inputs, one should be aware that the time estimates are extremely critical in the usage approach and may considerably impact the results, costs as well as resource requirements.

Recognizing the potential of the model, five European NS-RO have embarked on country-based real-life data collection to populate the TD-ABC model, which will complement the modelled inputs and allow to benchmark theoretical and real-life results. It is expected that the generation of different sets of real-life data will converge towards a more refined knowledge of national EBRT resource requirements and costs. Country-level data collection is fostered by information-sharing amongst different stakeholders, while some countries use extrapolation from different departments to the national level. This broadens the use of the model beyond its original goal to support national policy-making, allowing departments to use the insights for departmental management purposes as well. Moreover, the comparison between departmental and nation-wide applications is expected to shed light on the remaining questions regarding the impact of geographical spread and hospital overhead.

In conclusion, the presented ESTRO-HERO TD-ABC tool can model EBRT costs and resource requirements. While the Europalia example illustrates its potential, the results cannot be generalized nor used as a proxy for national evidence. Only real-world data, tailored to the specificities of individual countries, will be able to support the NS-RO in their strive for adequate investment planning and access to innovative radiotherapy.

Declaration of Competing Interest

The authors have no conflict of interest to declare.

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Appendix A. Supplementary data

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