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COMPARATIVE ASPECTS OF PARETO EFFICIENCY IN COMPUTED TOMOGRAPHY SERVICES

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Key words: computed tomography, radiology, Pareto optimum, efficiency, productivity, availability of services.

Summary

When the economic allocation of resources in any system is not Pareto efficient, there exists possibility for the Pareto improvement. In this paper the means of attaining the Pareto efficiency in providing services of computed tomography is discussed and compared. The study aims at analysing the use of computed tomography for the purpose of providing healthcare services in the European Union and other countries by making comparisons of data collected by the State Health Care Accreditation Agency under the Ministry of Health of the Republic of Lithuania. Using the methods of benchmarking and synthesis, authors seek to determine the potential efficient uses of computed tomography and propose the possible solutions for achieving the Pareto efficiency.

Introduction

At present, Lithuanian healthcare institutions use a number of expensive medical devices[1] which facilitate the diagnosis and treatment of a disease and help monitor its course. The issue of the efficient use of expensive medical devices in providing health care services is of special relevance both in Lithuania and globally.

Computed tomography (from '*tomos*' – slices, '*graphos*' – I write) is one of the most common methods of radiological examination performed using a computed tomography apparatus which is attributed to expensive medical devices. Computed tomography produces body images in a fast and precise manner, including the imaging of brain, thorax, spinal column and abdomen/pelvis; imaging is used also in neurology (for vascular examination), surgery (for biopsy from a precisely defined area), oncology (for planning radiotherapy), infectology (for diagnostic purposes of infections), etc. Not with standing the medical efficiency and benefits of the method of radiological examination, the issues concerning the economic efficiency[2] and effectiveness of its use give rise to wide-ranging debates respecting both the effects of examination of people (ionising radiation) and the effectiveness of the application of devices as such (tomography scanners) (high testing costs, inadequate availability of services, issues related to the validity of prescribing a test, etc.).

Where the economic allocation of resources in any system is not Pareto defisas efficient, there exists posssibility for the Pareto improvement – an increase in the Pareto efficiency[3]: a change to a different allocation that makes at least one individual better off without making any other consumer worse off. What are the means of attaining the Pareto efficiency in providing services of computed tomography in healthcare institutions?

Objective of the study. Overview of the key comparative aspects of the use of computed tomography in providing healthcare services in Lithuanian and foreign healthcare faci-

[1]An expensive medical device according to the Guidance concerning "Procedures for Registration and Provision of Data on Expensive Medical Devices in Use" approved by 17 March 2011 Ordinance No T1-224 of the State Health Care Accreditation Agency under the Ministry of Health of the Republic of Lithuania – computed tomography apparatus (CT), MRI, gamma camera, mammography, linear accelerators, angiography, X-ray devices, sonography equipment and PET, which are acquired, fully or in part, using the monetary resources of the state budget and/or municipal funds, the price of purchase whereof (including accessories) exceeds the total of LTL 100 thousand and/or annual operational costs total at least 1 million Litas of the monies from the annual budget of the Compulsory Health Insurance Fund.

[2]Economic efficiency is understood in this context as creation of optimal benefits for individuals, not necessarily material or expressed in monetary value.

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lities, analysis of the measures application where of enables to achieve the Pareto efficiency when providing computed tomography services based on the above mentioned comparisons.

Materials and methods

The article gives an analysis of the use of computed tomography for the purpose of providing healthcare services in the European Union and other countries by making comparisons of data collected by the State Health Care Accreditation Agency under the Ministry of Health of the Republic of Lithuania. Using the methods of benchmarking and synthesis, we seek to determine the potential efficient uses of computed tomography and propose the possible solutions for achieving the Pareto efficiency.

Table 1. Comparison of population in foreign countries in 2002 and 2012
Source: Eurostat

Country	2002	2012	Change
EU-27	484,635,119	502,623,021	17,987,902
Belgium	10,309,725	11,094,850	785,125
Bulgaria	7,891,095	7,327,224	-563,871
Czech Republic	10,206,436	10,505,445	299,009
Denmark	5,368,354	5,573,894	205,540
Germany	82,440,309	81,843,743	-596,566
Estonia	1,361,242	1,294,486	-66,756
Ireland	3,899,702	4,582,707	683,005
Greece	10,968,708	11,290,067	321,359
Spain	40,964,244	46,196,276	5,232,032
France	61,424,036	65,327,724	3,903,688
Croatia	4,444,608	4,398,150	-46,458
Italy	56,993,742	59,394,207	2,400,465
Cyprus	705,539	862,011	156,472
Latvia	2,345,768	2,041,763	-304,005
Lithuania	3,475,586	3,003,641	-471,945
Luxembourg	444,050	524,853	80,803
Hungary	10,174,853	9,932,000	-242,853
Malta	394,641	417,546	22,905
Netherlands	16,105,285	16,730,348	625,063
Austria	8,063,640	8,443,018	379,378
Poland	38,242,197	38,538,447	296,250
Portugal	10,329,340	10,542,398	213,058
Romania	21,833,483	21,355,849	-477,634
Slovenia	1,994,026	2,055,496	61,470
Slovakia	5,378,951	5,404,322	25,371
Finland	5,194,901	5,401,267	206,366
Sweden	8,909,128	9,482,855	573,727
United Kingdom	59,216,138	63,456,584	4,240,446
Iceland	286,575	319,575	33,000
Norway	4,524,066	4,985,870	461,804
Switzerland	7,255,653	7,954,662	699,009
Turkey	68,838,069	74,724,269	5,886,200

The problem of the optimal number of computed tomography apparatuses. Comparative aspects. Prior to conducting a comparative analysis, it is important to consider certain factors which are relevant for assessing the use of computed tomography scanners (hereinafter – CT) in Lithuania and abroad. Population size is probably the a key factor.

When comparing Lithuania with the member countries of the Organisation for Economic Co-operation and Development (hereinafter – OECD) or the European Union, it should be noted that the population has been increasing in the countries of Western Europe over the last decade, whereas Lithuania and other countries of Eastern Europe have experienced a population decline (Table 1).

According to the data of the OECD, the number of CT in Europe has shown a significant growth over the last two decades. For instance, the number of CT in the Netherlands it has nearly doubled over the period from 1990 to 2010. The Italian figures are even more impressive: the number of CT increased almost six-fold in the period from 1997 to 2010. In 2010 Greece, Italy, and Cyprus had the largest numbers of CT per 1 million inhabitants among the member states of the European Union. The figure for Iceland and Switzerland, countries outside the European Union, however, was substantially higher than the average rate for the EU (Fig. 1).

Bulgaria and Romania have the lowest rate of CT per one million inhabitants. These figures, however, do not allow drawing unequivocal conclusions since no general guidelines according to the OECD exist in relation to an ideal rate of CT in regard to population size. It should be pointed out in this particular respect that smaller numbers of devices may give rise to problems of access geographically resulting in long waiting lists. On the other hand, an excessive quantity of these devices, not infrequently, cause an inappropriately intensive use of the expensive procedures which, in its turn, yields little or hardly any benefit to a patient [1].

As mentioned above, the highest numbers of available CT in 2010 were in Cyprus and Greece, the rate being 33.6

[3] The Pareto efficiency, or the Pareto optimality, is a state of allocation of resources in which it is impossible to make any one individual better off without making at least one individual worse off. The term is named after Vilfredo Pareto (1848–1923), an Italian economist who used the concept in his studies of economic efficiency and income distribution. The concept has applications in academic fields such as economics, engineering, and the life sciences).

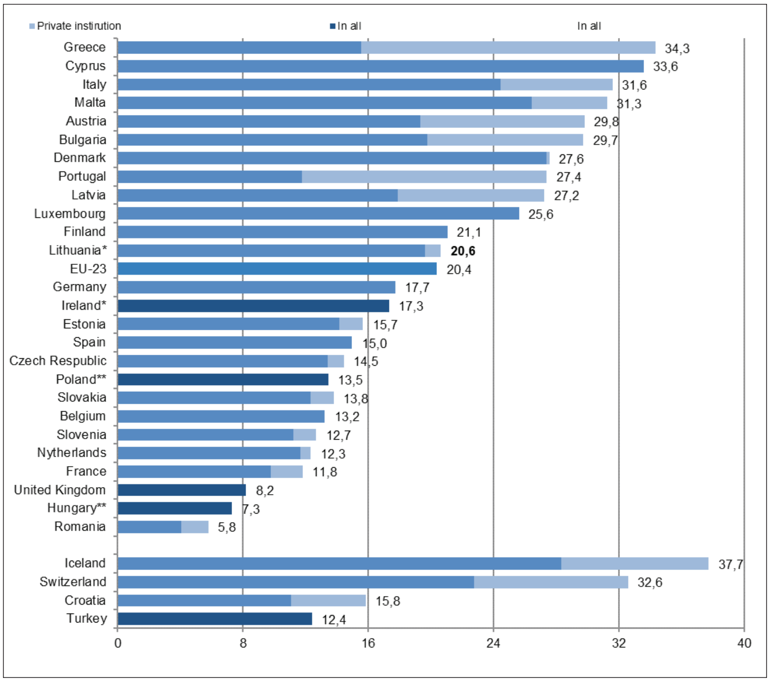

Fig. 1. Number of CT per 1 million inhabitants
*Source: OECD. Note: * - 2012 data, ** - 2011 data, otherwise 2010 data [2].*

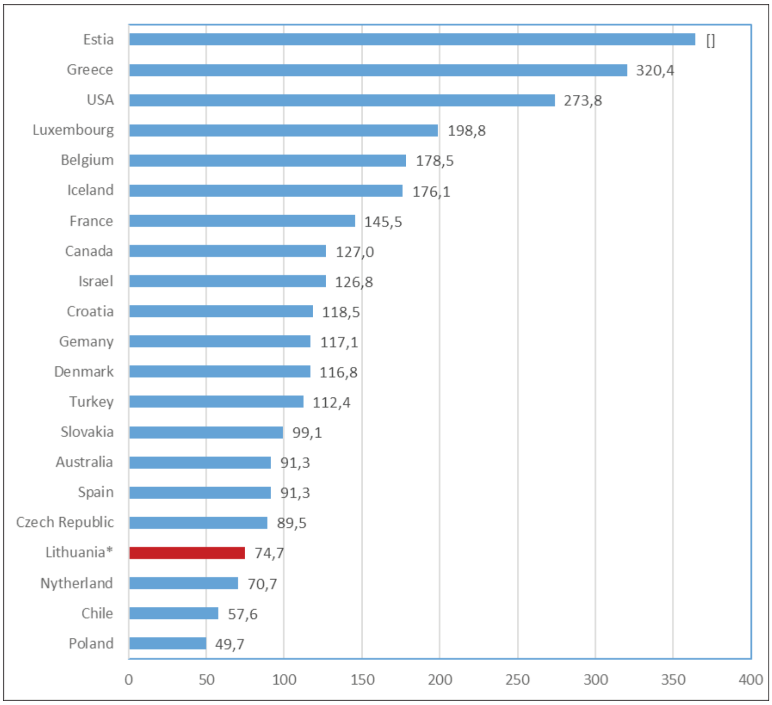

Fig. 2. Number of computed tomography tests per 1 thousand inhabitants, 2011 or the latest available data. * - 2012 data
Source: OECD, SHCAA.

CT per 1 million population in Cyprus and 34.3 CT in Greece, whereas Switzerland, Iceland, Italy, Austria, Denmark, and other countries had a significantly higher rate of CT in comparison to the average for the EU-23, which was ca. 20.4 per 1 million inhabitants in 2010. It should be noted, however, that the recorded numbers of CT in Europe are far lower when compared to Japan or the United States. The lowest rates of CT per 1 million inhabitants were meanwhile recorded in Hungary and Romania (7.3 and 5.8 per 1 million people, respectively) [1].

When analysing the above data, it is important to take into account specific causes and particular governmental regulations applicable to the acquisition and use of medical equipment existing in each country which, to a large extent, influence the variation in the CT rates. For instance, the majority of CT, in Greece are installed in private diagnostic centres and only a small fraction in public hospitals. Acquisition of CT is subject to regulation in this country; CT acquisition requires a licence which is issued after a review is conducted based on the criterion of population density. No guidelines for the use of CT exist here. In order to address this problem, the Greek Ministry of Health and Society Solidarity even decided to establish a committee of experts for the purpose of analysis and elaboration of proposals regarding the new criteria for CT acquisition.

Based on the data for 2011 or the latest available data of the OECD and the information for 2012 produced by the State Health Care Accreditation Agency under the Ministry of Health (hereinafter SHCAA), in terms of the rates of CT examinations per one thousand people, in 2012 Lithuania surpassed Chile (57.6 per 1 thousand population),the Netherlands (70.7 per 1 thousand population), and Poland (49.2 per 1 thousand population), whereas the neighbouring Estonia (364.3 per 1 thousand population) in this respect outstripped even Greece which had the highest number of CT per one million inhabitants, (320.4 per 1 thousand population) (Fig. 2).

It should be further noted that the data obtained from other countries also testify to the fact that the number of CT units per 1 million people does not necessarily correlate with the rates of CT tests per 1 thousand population, it being even inversely proportional. For instance, the number of CT per 1 million inhabitants in Belgium, France, Spain, or Germany is lower than the figure for Lithuania, whilst the number of examinations performed per one thousand inhabitants is higher. This ratio should be approached with especial caution since high numbers of services provided do not necessarily reflect the need to provide such services [3].

A good illustration of this tendency is given by the situation in the US where CT examinations constitute a widespread misuse when they are performed without any reasonable need. The number of CT testing considerably grew in 1997 to 2006; the incidence of diseases detectable by means of such equipment, however, has remained on the same level [3]. A flawed compensation policy, when physicians are financially motivated to refer a patient for CT examination, may add to such misuse of costly tests in the US [4]. Other OECD countries are also considering options for a more prudential CT acquisitions and uses. The National Institute for Health and Clinical Excellence of the UK has appointed the Diagnostics Advisory Committee charged with the task to assess and give suggestions concerning a proper use of diagnostic technologies [5].

Allocation and Use of Computed Tomography for the purpose of Healthcare Services in Lithuania. Based on the data for 2012 provided by the SHCAA, 39 Lithuanian health care institutions (hereinafter – HCI) had 62 CT units

Table 2. Allocation of computed tomography units in Lithuanian HCI
Source: SHCAA, 2012.

No.	Institution	Available CT	Year of acquisition	Years in operation	Slices	Number of examinations in 2012
1	PI Alytus County S. Kudirka Hospital	1	2008	5	16	8064
2	PI Anykščiai District Municipal Hospital	1	2007	6	2	2054
3	PI Joniškis Hospital	1	2007	6	4	2434
4	PI Kaunas Dainava Hospital	1	2007	6	6	5595
5	PI Kaunas Clinical Hospital	2	2008	5	16	5810
			2012	1	128	2253
6	PI Kaunas Republican Hospital	1	2011	2	64	5351
7	PI Kėdainiai Hospital	1	2007	6	16	4243
8	PI Klaipėda Children's Hospital	1	2007	6	8	2138
9	PI Klaipėda Seamen's Hospital	2	2004	9	64	5721
			2009	4	4	276
10	PI Klaipėda University Hospital	3	2008	5	40	821
			2004	9	16	10106
			2007	6	64	1159
11	PI Hospital of Lithuanian University of Health Sciences (LUHS) Kaunas Clinics	7	1999	14	6	6917
			2009	4	16	2852
			2004	9	16	13184
			2010	3	64	6793
			2009	4	16	1396
			2012	1	1	
			2012	1	640	969
12	PI Marijampolė Hospital	1	2011	2	16	3938
13	PI Mykolas Marcinkevičius Hospital	1	2003	10	2	5053
14	PI Panevėžys Hospital	2	2009	4	64	2496
			2005	8	16	7226
15	PI Pasvalys Hospital	1	2005	8	1	3543
16	PI Plungė District Municipal Hospital	2	2006	7	4	809
			2012	1	16	1168
17	PI Raseiniai Hospital	1	2008	5	6	2280
18	PI Telšiai Regional Hospital	1	2003	10	2	4105
19	PI Klaipėda Republican Hospital	2	2007	6	40	3066
			2011	2	16	5543
20	PI Republican Vilnius University Hospital	2	2005	8	16	10401
			2012	1	128	1747
21	PI Vilnius Republican Psychiatric Hospital	1	2002	11	1	1565
22	PI Rokiškis District Hospital	1	2004	9	1	2208
23	PI Šiauliai Republican Hospital	4	2007	6	64	4025
			2005	8	4	7530
			2009	4	16	1040
			2007	6	16	522
24	PI Šilutė Hospital	1	2004	9	1	3115
25	PI Tauragė Hospital	1	2006	7	16	4258

in the period from January 2012 to December 2012, including 3 private establishments (Table 2). Eight new CT units were acquired in the year 2012. Below, an analysis of data on the CT in use for 2012 is given.

According to the SHCAA data, there were 20.64 CT per 1 million people in Lithuania in 2012 (to compare: 18.49 CT in 2011, with the population of 3052588). As mentioned above, no general guidelines regarding the optimal numbers of CT units exist in the OECD countries; each country, therefore, must estimate its demand individually.

The major part of CT in use at HCI was manufactured between 2007 and 2012 (Fig. 3). In 2013, 5 CT in use were manufactured more than 10 years ago, which accounted for 8 percent of the total number of CT units available in Lithuania. The oldest CT, made in 1999, remains in use in the Hospital of Lithuanian University of Health Sciences (LUHS) Kaunas Clinics.

The Decree No. V-831 of the Minister of Health of the Lithuanian Republic "Re: Approval of depreciation and amortisation rates applicable to fixed assets in respect of healthcare public sector entities", dated October 1, 2009, determined the 6-year period rate of depreciation for medical equipment, i.e. 16.7 percent annually, the monthly depreciation rate being 1.4 percent [7]. The minimum rate of depreciation for medical equipment is 5 years and the maximum rate is 10 years [8].

The service life of medical devices is of paramount importance for several reasons.

26	PI Ukmergė Hospital	1	2008	5	16	3312
27	PI Utena Hospital	1	2011	2	16	3362
28	PI Vilnius City Clinical Hospital	2	2006	7	16	2731
			2007	6	6	588
29	PI Vilnius University (VU) Institute of Oncology	2	2007	6	32	9523
			2011	2	16	2366
30	PI Children's Hospital, Branch of the Vilnius University Hospital Santariškių Clinics	1	2010	3	64	2804
31	PI Vilnius City Clinical Hospital Antakalnis Branch	1	2008	5	16	1922
32	PI Vilnius University Hospital Santariškių Clinics	4	2004	9	16	5040
			2007	6	64	3291
			2007	6	16	11518
			2012	1	128	
33	PI Vilnius University Hospital Žalgirio Clinics	1	2002	11	1	841
34	PI Vilkaviškis Hospital	1	2006	7	4	2411
35	PI Visaginas Hospital	1	2007	6	32	2960
36	Medea diagnostic, UAB	1	2008	5	16	3312
37	Kardiolita, UAB	2	2006	7	2	3102
			2012	1	64	1548
38	SK Impeks medical diagnostic's center, UAB	1	2009	4	128	n.d.
39	The State Forensic Medicine Service under the Ministry of Justice of the Republic of Lithuania	1	2012	1	16	n.d.
	Total:	**62**				**224405**

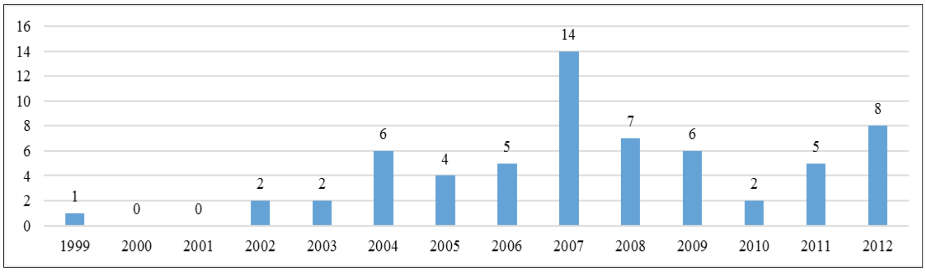

Fig. 3. Breakdown of computed tomography scanners based on the year of manufacture
Source: SHCAA, 2012.

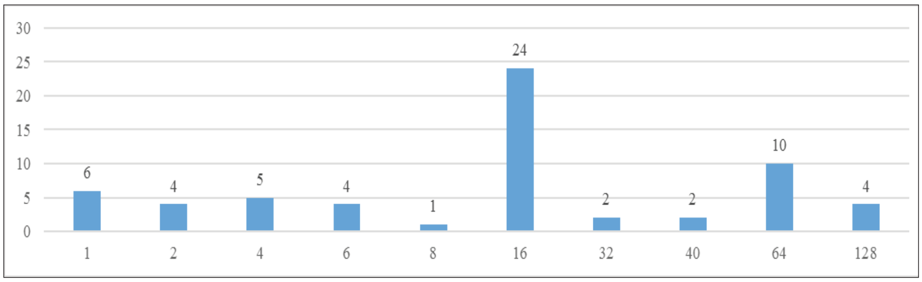

Fig. 4. Breakdown of computed tomography scanners based on the number of slices in Lithuania, 2012.
Source: SHCAA, 2012.

According to the Canadian Association of Radiologists, the obsolete equipment increases the likelihood of breakdowns and failures during a procedure. Also, the Association says that spare parts for outdated equipment are harder to obtain and its maintenance costs tend to inflate. The Association recommends an eight-year service life for computed tomography apparatuses [9]. The European Coordination Committee of the Radiological, Electromedical and Healthcare IT Industry (COCIR) recommends that 60 percent of the equipment in use should be up to 5 years old or newer; equipment that has been in use for 6 to 10 years should account for 30 percent at most, while equipment older than 10 years should make up maximum 10 percent of the total units in use, and points out that the replacement of the latter is deemed essential [10].

According to the SHCAA data, all the CT apparatuses available at the Lithuanian HCI are stationary system units. The breakdown of CT according to another technical parameter – the number of slices – is given below. The given information shows that more than a third (38 %) of CT are 16-slice scanners, 96 % are 1-slice, and 16 % – 64-slice units. According to the 2012 data of the SHCAA, there were four 128-slice CT scanners in Lithuania (Fig. 4).

Enhancing the Pareto efficiency in computer tomography as proposed by Giles Boland and other scientists.

The article *CT Productivity: Good for Patients, Referring Physicians, and the Bottom Line*, dealing with the issue of enhancement of CT productivity and published by Giles Walter Boland, MD, a celebrated professor of radiology at the Harvard Medical School (US), proposes several simple ways how to increase the number of examinations without increasing the quantity of available CT machines and thereby saving costs [11].

The scientist acknowledges that, al though CT is efficient in diagnosing a vast array of medical conditions, it has also its shortcomings. These include a patient being exposed to ionising radiation and the very price of a CT machine. Moreover, CT is less informative in comparison to the magnetic resonance imaging tests, and CT has less capacities as compared to MRI, however, where there is a need for expedite examination, when dealing with an agitated patient, and for the purpose of visualising acute intracranial haemorrhages, bone fractures, laccinates, and similar conditions, this method of examination has its advantages. Furthermore, CT may also be used for testing claustrophobic patients and in case of contraindications for magnetic resonance imaging scan being in place [6].

Many radiology departments are struggling to keep up with the increasing demand, yet patients and referring physicians expect, and even demand, that requested scans be performed quickly [11]. Any wait for appointments can delay an important diagnosis, and both patients and referring physicians may choose to be scanned elsewhere if they can obtain an earlier appointment. Meanwhile, CT has become highly profitable, and any loss of patient volume, either due to poor productivity or because of loss of market share, can have a significant negative effect on the organization's bottom line. The net sum of all these pressures is that radiology managers are expected to provide a rapid access to CT for referred patients and, in turn, increase CT capacity.

A frequent initial response to the demand for increased CT accessibility and productivity is to purchase a new CT equipment. While this ultimately may be necessary, invariably, many CT machines are not operating at the optimal capacity. This leads to the conclusion that decisions to purchase additional equipment are often made before the full capacity of CT has been realized, resulting in an unnecessary financial burden. A more rational approach, both in financial and logistical terms, would be to re-evaluate critically the existing workflow and operations in the performance of CT examinations. However, it is important to state that such evaluation becomes economically efficient only when planning the future investment into the development of CT services indirect costs, including the installation accommodation of additional space, staff and or its training, which constitute the total costs of services and are taken into account in addition to the estimates of direct costs related to an alternative option (purchase of new equipment) [11].

The process optimisation is apparently one of the key factors to attain the Pareto efficiency, given a proper balancing. In addition to the key measure for the improvement of CT productivity, i.e. performing more scans during a given time period, there is an option – to extend the working hours of departments providing CT examinations. These two concepts, while simple, are often neglected.

Scanning more patients in a given time period (say, per hour) is initially achieved, as already mentioned, by evaluating the workflow of the CT operation to look for bottlenecks, delays and inefficiencies in the system. An increase in CT productivity often requires preparing and evaluating flowcharts for the whole CT operation (from the time of referring a patient for CT examination until the production of results) [11]. MacDonald S. L., Cowan I. A., Floyd R. A. et al., using the process monitoring and IT techniques, monitored and measured the workload of radiologists at the Christchurch hospital (New Zealand) for the period of three years. The scientists identified six broad categories of clinical activities contributing to a radiologist average daily workload and measured the average time spent on each activity: a) diagnostic reporting accounted for approximately 35 %

of radiologist clinical time; b) performance of radiological examination (procedures) – 23 % of the working time; c) medical staff supervision – 23 % of the time; d) conferences and professional development related activities – 14 %; e) informal case discussions, consultations with staff members concerning clinical cases – 10%; and f) referral-related administration – 3%. A transparent and robust method of measuring radiologists' scope of work has been developed based on this research which can be used for planning workloads and optimising the processes which cause an inefficient waste of the working time of staff [14].

Seeking to reduce any delays in the workflow process, it should be ensured that patients arrive on time, are scanned on time, and leave on time. This can be challenging for hospital CT scanners, where inpatients and outpatients are typically imaged on the same scanner. Urgent inpatient emergency scans will usually trump non-urgent scans for outpatients who are then sometimes left waiting for hours for their scans. Further, due to the complexity of manoeuvring critically ill patients in and out of CT scanners, the workflow can be severely disrupted at the CT suite. It may make sense, therefore, to image inpatients and outpatients on different scanners so that the CT workflow can be optimised for both groups of patients [11].

One of the largest bottlenecks in the workflow is the speed with which CT technologists can move patients in and out of the CT suite. There are numerous tasks that these technologists (or technologist aids) have to perform in order to process a patient through the CT scan. These range from preparing the CT machine itself for the appropriate scan to explaining the procedure to the patient [11].

Given the multiplicity of tasks required, it is surprising that many managers operate CT machines with a single technologist. These managers may believe that they are saving costs, but in reality, they are missing a huge opportunity to increase productivity (and, consequently, customer service and financial return). Rather, it is far more prudent to operate these expensive machines with multiple personnel who can now divide the workload among them selves so that many procedures can be performed simultaneously. This multitasking by multiple individuals should considerably expedite the transfer of patients in and out of the CT suite. Not all of the individuals need to be radiologists or technologists to perform certain tasks. Some tasks can be performed successfully by nurses or technologist aides. What really matters is that the outcome calculated on the process optimisation is achieved – the quality of provided services is improved and the speed of services increased. While the cost of examination would clearly increase due to the newly employed staff, CT productivity can triple, with the resulting revenue far outstripping (by a factor of 10 to 20) the cost of employing these new individuals [11]. Thus, the Pareto optimality principle can be achieved to the utmost extent.

In the summer of 2008, Giles L. Boland, in conjunction with his fellow researchers, attempted to verify in practice his theoretical considerations and conduct a research with a view of maximising outpatient computed tomography productivity using multiple technologists, the results of which were published in the *Journal of the American College of Radiology* [12]. The study claims that the number of patients that a single technologist can scan is limited because of the many tasks required to process a patient through a CT scan. However, many tasks could be performed simultaneously involving additional personnel by using a multiple technologist model in a single CT scanner room. During the research 34, technologist workflow tasks were identified and a total of 205 outpatients were evaluated. Measurements were made in order to enhance the productivity of the multidetector CT and increase the patient throughput using a 2- and 3-technologist model instead of a single technologist. It was calculated that the total time to perform general tasks (excluding CT scanning) when preparing for CT examination for 1-, 2-, and 3-technologist models was 27,

Table 3. CT productivity model A

Number of technologists	**Number of patients per week**		**Number of patients per year**	
	100% CT capacity	**85% CT capacity**	**100% CT capacity**	**85% CT capacity**
1	120	100	6240	5200
2	285	240	14820	12480
3	415	355	21580	18460

Table 4. CT productivity model B

Number of technologists	**Number of patients per week**		**Number of patients per year**	
	100% CT capacity	**85% CT capacity**	**100% CT capacity**	**85% CT capacity**
1	207	174	10764	9048
2	514	436	26728	22672
3	745	634	38740	32968

23, and 22 minutes, respectively. In case of model A (Fig. 3), the number of patients processed through the scanner in an eleven-hour working day at a 100 % capacity was 24, 57, and 83 (20, 48, 71 patients at 85 % capacity) using 1-, 2-, and 3-technologist model, respectively. Below, we give a possible CT throughput (estimated at a 100 % and 85 % operating capacity; when CT is used for 11-hour long 5 workdays per week; 1-, 2-, and 3-technologist models compared) [12].

At the same time that the patient CT throughput is optimised, the question of extending the hours of operation should be given a serious consideration. Many organisations operate their scanners after hours for emergency purposes only, either believing that the costs are too high to operate at full staffing levels or that outpatients are unwilling to attend after hours. For hospital facilities, as the author points out, the scanner should continue to operate after hours in order to scan the less urgent inpatients (who are on-site anyway), while outpatients can be scanned during the regular working hours. Outpatient-dedicated scanners should be made available on weekends as well, while managers can be comforted that the revenue from two to three patients will usually cover the operating costs of opening on a weekend day, at the same time contributing to the regulation of patient flows [11].

The above-mentioned study [12] gives a second model when the CT equipment is used for 15 hours on weekdays and 12 hours on weekends (Fig. 4). It was measured that 31, 78, and 113 patients can be processed through the CT scanner in a 15-hour workday (26, 62, 96 patients at a 85 % capacity) using 1-, 2-, and 3-technologist model, respectively. It was estimated that, using the CT scanner for 12 hours on a weekday, 26, 62, and 90 patients can be scanned, respectively, when using the three operating models (22, 53, 77 patients at 85 % capacity). It was estimated that 38,740 patients can be processed annually using a 3-technologist model, whereas only 10 thousand patients are scanned per year when using a single-technologist model.

A single-technologist model for outpatient multidetector CT is inefficient with the limited possibility for increased patient throughput, unless hours in operation are added. The use of multiple technologists (or other key personnel) optimizes CT throughput and capacity, particularly with a 3-technologist model, which can yield a greater than threefold increase in CT productivity.

Combining an extended CT schedule with an increased patient throughput should result in CT operators meeting, and sometimes exceeding, the intended numbers of examinations. Patients are comforted by being scheduled quickly, without being on a waiting list for weeks or even months, and by being able to hear test results in the shortest possible time. Administrators are reassured that the radiology department is providing superior customer service, and CT equipment is utilized in a rational and efficient way.

Equally important is the issue of quotas available for healthcare facilities. Failing to increase them, the so-called "creaming" effect [13] may continue to persist when institutions avoid patients referred from outside institutions by giving preference to the patients treated in their facilities. In such event, other institutions seek for possible solutions which, as often as not, involve the demand for the purchase of a new CT equipment.

Having taken into account the above recommendations of scientists and adapting them in Lithuania, it must be concluded that the acquisition of new CT apparatuses for non-hospital level healthcare facilities is unviable since the major hospitals in Lithuania already have such equipment, yet the latter, based on available data, fail to utilise their potential resources due to both fixed quotas and for the aforementioned reasons.

CT apparatuses and examinations in specialised HCI should not be questioned having in mind the specific nature and complexity of examinations. On the other hand, considering a high concentration of CT apparatuses in Vilnius, Kaunas, and Klaipeda, it is noted that some facilities are situated from each other at a distance of mere 200 metres or even housed in the same building, each facility, meanwhile, either possessing its own CT unit or seeking to acquire it. In this and the above-listed cases, applications for the acquisition of new equipment should be approached in threefolvays: 1) purchase of CT equipment for the purpose of the introduction of new services; 2) purchase of CT equipment on the grounds that the available CT resources are inadequate; 3) purchase of CT equipment in order to upgrade or renew it. Taking into consideration the current situation in Lithuania, the latter option is deemed the most prudent one. The second option could be viable only if and when all available technical and administrative possibilities have been exhausted.

Conclusions and proposals

1. The total numbers of computed tomography units have significantly increased in Europe over the last decades. Although the rate of computed tomography units per one million inhabitants in large member states of the European Union (France, Spain, Germany) is significantly lower than the same figure for Lithuania, the rate of computed tomography services (examinations performed) per one thousand population, however, is considerably higher. On the one hand, this demonstrates a more efficient utilisation of these devices; and on the other hand, there is a need to analyse the figures of the relevancy of referrals for this type of examination.

2. Based on the worldwide practice and recommendations of scientists concerning the increase in CT productivity, it is suggested that, seeking to attain the Pareto efficiency, instead of enhancing geographical accessibility,the productivity and efficiency of the available CT apparatuses should be enhanced by reviewing and optimising processes at radiology departments (if applicable – by extending the hours of radiology departments and considering the option of enlarging the staff).

3. CT equipment should be purchased only with a view to introduce new services, even in this case, however, a prerequisite economic analysis of the demand of such services and the expected return of intended investments should be conducted. Bearing in mind that the projections of population growth in Lithuania are negative, the feasibility of purchasing of new CT apparatuses for the purpose of provision of new services in healthcare facilities is rather dim.

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PARETO OPTIMUMAS TEIKIANT KOMPIUTERINĖS TOMOGRAFIJOS PASLAUGAS. LYGINAMIEJI ASPEKTAI

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Raktažodžiai: kompiuterinė tomografija, radiologija, Pareto optimumas, efektyvumas, produktyvumas, paslaugų prieinamumas.

Santrauka

Lietuvos sveikatos priežiūros įstaigose šiuo metu naudojama nemažai brangių medicinos prietaisų, kurių pagalba galima diagnozuoti žmogaus ligą, ją gydyti, stebėti jos eigą. Brangių medicinos prietaisų efektyvaus panaudojimo, teikiant asmens sveikatos priežiūros paslaugas, problema aktuali tiek Lietuvoje, tiek kitose pasaulio šalyse. Kompiuterinė tomografija („tomos" – pasluoksniui, „grafos" – rašau) – vienas iš populiariausių radiologinių tyrimo metodų, kuris atliekamas brangiems medicinos prietaisams priskiriamu kompiuteriniu tomografu. Kompiuterinės tomografijos metu greitai ir tiksliai atliekamos kūno nuotraukos, į kurias įeina

smegenų, krūtinės, stuburo ir pilvo/dubens nuotraukos, tyrimas taip pat naudojamas neurologijoje (tiriant kraujagysles), chirurgijoje (atliekant biopsiją iš tiksliai nustatytos vietos), onkologijoje (planuojant radioterapiją), infektologijoje (diagnozuojant infekcijas) ir kt. Nepaisant šio radiologinio tyrimo metodo medicininio efektyvumo ir pranašumo, su jo panaudojimo ekonomiškumu ir efektyvumu susiję klausimai yra sukeliantys plačią diskusiją, tiek dėl tyrimo poveikio žmogui (jonizuojanti spinduliuotė), tiek dėl pačių prietaisų (tomografų) panaudojimo produktyvumo (brangūs tyrimo kaštai, nepakankamas paslaugų prieinamumas, su tyrimo skyrimo pagrįstumu susiję klausimai ir kita). Jeigu ekonominis išteklių paskirstymas bet kurioje sistemoje nėra Pareto efektyvus, egzistuoja galimybė Pareto patobulinimui – Pareto efektyvumo padidinimui: perskirsčius išteklius ir pagerinus bent vieno vartotojo gerovę, nepabloginus kito vartotojo gerovės. Kokiomis priemonėmis įmanoma pasiekti Pareto efektyvumo teikiant kompiuterinės tomografijos paslaugas asmens sveikatos priežiūros įstaigose?

Tyrimo tikslas. Apžvelgti reikšmingiausius kompiuterinių tomografų panaudojimo teikiant asmens sveikatos priežiūros paslaugas Lietuvos ir užsienio įstaigose lyginamuosius aspektus, jų pagrindu išanalizuoti priemones, kurias taikant įmanoma pasiekti Pareto efektyvumo teikiant kompiuterinės tomografijos paslaugas.

Medžiaga ir metodai. Straipsnyje analizuojamas kompiuterinių tomografų panaudojimas asmens sveikatos priežiūros paslaugų teikimui Europos Sąjungos ir kitose užsienio šalyse, lyginant jį su Lietuvos valstybinės akreditavimo asmens sveikatos priežiūros veiklai tarnybos prie Sveikatos apsaugos ministerijos surinktais duomenimis. Taikant lyginamosios analizės ir sintezės metodus, siekiama išsiaiškinti kompiuterinių tomografų efektyvaus panaudojimo galimybes bei pasiūlyti galimus sprendimų būdus Pareto efektyvumui pasiekti.

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