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Distribution and Use of Mammography Units in Greece

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ABSTRACT

Purpose: Mammography is the best screening practice for early diagnosis of breast cancer, which remains the leading cause of cancer death for women below seventy years of age. The availability of mammographic units (MUs) that can be easily accessed by the female population is very important for the early diagnosis of breast cancer. In this study, the distribution and use of MUs is investigated to provide an overall image of the implementation of this technology in Greece.

Materials and Methods: The relevant information and data collected in the present work are based on cross-referenced sources like OECD, WHO and EEAEA. A comparison is performed between 2021 and 2017 on the per population number of MUs installed, analyzed per administrative region, technology and public/private sector. The Lorenz curves and Gini coefficient metric were employed to assess the inter-regional equity of the MUs distribution.

Results: Greece has one of the highest numbers of MUs per population, well above the European average. However, the use rate remains unknown. Coverage is still lacking in some Aegean Sea islands, although the inequity observed in the distribution of MUs installed is low. The private sector is dominant representing 82% of the total 732 MUs installed. Moreover, 43% of the total units installed are using the outdated technologies of film and CR imaging. Nevertheless, the replacement of older equipment and a shift to more modern technologies is a recurring pattern in the last years and can lead to better cancer diagnosis.

Conclusions: Strategic planning of investments in new technologies and medical equipment distribution is a significant factor for reducing inequity and making healthcare technologies more accessible to the public.

KEY WORDS

Health-care; Medical Technology; Mammography unit; Medical equipment distribution; Gini coefficient

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Introduction

1. Introduction

Advances in biomedical research are leading to a storm of innovation and the resulting development of new diagnostic and therapeutic devices have led to an essential improvement of the current health-care delivery. As a result, modern medicine is strongly dependent on technology [1]. However, it is often questionable whether the extent of technology in use today is evidence based or excessive.

WHO has published a general method for conducting a needs assessment regarding medical equipment in use at regional or national level, by evaluating what should be available according to particular demands and needs, while also taking into account local epidemiological data, as well as clinical best practices and guidelines [2]. By considering this, alongside with possible economic constraints, the actual potential benefit from a given technology can be identified.

Breast cancer remains the most common cause of death for women below seventy years of age. One in ten European women develops this type of cancer in her lifetime. Early diagnosis is recognized as one of the most critical factors that improve the chance of survival. X-ray Mammography is considered the best practice for screening. Therefore, the availability of mammographic units (MUs) that can be easily accessed by the female population in the country is very important for early diagnosis of breast cancer.

An assessment of the distribution and utilization of high value capital medical equipment in Greece, performed in 2017 by the Institute of Biomedical Technology (INBIT) under WHO Athens office assignment, provided an in-depth analysis of the regional distribution, use and costs for specific categories of radiotherapy and imaging equipment, including Mammography [3].

The present study aims to assess the sufficiency and equity in the distribution of MU technology in Greece, to identify eventual inequalities in terms of geographical coverage, specific needs or lack of these technologies and investigate the above trends in recent years.

2.Materials and Methods

a. Data Collection

It is important to note that reliable data on the installed technological infrastructure and evidence-based needs assessment are prerequisites for an effective use of such a model. The general information sources for this study were data available from international organizations such as WHO, Organization for Economic Co-operation and Development (OECD), European Union (EU), ECRI institute and other reliable sources in the internet. Furthermore, the global scientific and technological literature, the standards and best practices in use, as well as the present trends on various technologies were taken into account.

On the other side, there is no centralized national inventory for the installed high value capital equipment in Greece, so the respective information and data collected and used in this study concerning MUs are based on various sources. There are also no available data related to the actual use of these technologies, except for indirect information on those procedures that are reimbursed by the National Organization for Healthcare Provision (EOPYY). Nevertheless, these data do not present the full picture regarding the actual use and the related expenses, since the numbers of diagnostic and therapeutic procedures not reimbursed by EOPYY are unknown.

In the present work, due to the lack of a concrete set of reliable data, a great number of different sources had to be used. The relevant information and data collected are based on various cross-referenced sources from the Greek Atomic Energy Commission (EEAE), the National Evaluation Centre of Quality and Technology in Health (EKAPTY), the Federation of Technologists Radiologists of Greece (OTAE) and the inventory for medical devices created in 2015 by the Biomedical Technology Unit (BITU) of the University of Patras. However, this multisource based search creates a series of issues regarding data integrity, compatibility and reliability. The existing data from international organizations (e.g. WHO, OECD) are also based on these primary, so discrepancies in the numbers of the installed medical equipment in Greece may be found. Indeed, most of these sources were set up to provide specific reasons, other than a continuously updated and reliable medical devices inventory. For example, the EEAE database on medical equipment using ionizing radiation, considered the most reliable source, focuses on licensing and radiation safety issues, and does not gather information on the year of manufacture or of entry into service. Hence, the existing data do not reflect the actual status of the installed MUs at a certain moment. Additionally, direct data regarding the actual use of the units are not available, except for information on the procedures that are reimbursed by the EOPYY.

Taking into consideration the information found in

Table 1. Populations of Greek administrative regions, 2011 census [3].

Regions	Population (thousands)
Attica	3,833
Central Macedonia	1,882
Thessaly	732
Western Greece	679
Crete	623
Eastern Macedonia and Thrace	608
Peloponnese	577
Central Greece	547
Epirus	336
South Aegean	306
Western Macedonia	283
Ionian Islands	207
North Aegean	199

these various sources, the analysis focuses on the current MUs installed as of January 2021, compared to the ones existing up until November 2017 that are available in the study mentioned before [3]. Data are classified and presented per administrative region where each unit is put into service. Population data are based on the 2011 census, due to the lack of a more recent one (**Table 1**).

b. Statistical Analysis

In order to examine the geographical equity of the number of MUs per 100,000 inhabitants between regions, we used the Lorenz curves and Gini coefficient. The Gini coefficient is a popular index of income equality used in economics, that has also widely been used in health-related applications, such as public health and epidemiology [4,5]. In this study, we define the medical equipment as the resources of each region and calculate the unevenness of it among Greece's regions using the Gini coefficient.

We first constructed the Lorenz curves for the technology examined. This was done by ranking all of Greece's regions by the number of units per 100,000 inhabitants. Then, each region was placed on a x-y plane, with its x coordinate being the accumulative percentage of the population, and its y coordinate being the accumulative percentage of examined modality units.

Having plotted the Lorenz curves for the MUs, the Gini index can be calculated as the area between the Lorenz curve and the 45-degree line, divided by the area under the diagonal line [6]. The Gini index can range from 0, that presents absolute equity, to 1, which means complete inequity [7]. A Gini coefficient less than 0.2 corresponds to low inequity level; between 0.2 and 0.3 there is moderate inequity; for values in the range of 0.3 and 0.4 there is high inequity, while for a Gini index over 0.4 there is extreme inequity [8]. Using the Lorenz curves, we can have a qualitative description on the equality. The Gini coefficient on the other hand, can show in quantity the changes in inter-regional equality over time. Using these tools, we can examine the equality status on the distribution of MUs [9].

3. Results

The regional sector distribution of MUs in Greece in absolutes, as well as per inhabitant unit was first calculated (**Fig. 1a**). The total number of units is quite large and most of the regions show small fluctuations in the number of MUs per 100,000 inhabitants, but some stand out clearly.

It is apparent that MUs are available in almost all regional sectors in Greece. The few exceptions are found mostly in islands, like the smaller islands of Ithaca, Kea and Kythnos, but also in the much bigger and more highly populated islands of Thasos and Tinos. Hence, women in these regions who need mammograms must travel to a different island or to mainland Greece. The highest numbers of MUs per 100,000 inhabitants appear in the islands of Paros, Mykonos and Limnos, but this is because the metric is influenced by the low permanent inhabitants of these islands. Compared to the rest of the country, lower numbers of units per 100,000 inhabitants are shown in Fokida, Serres and Achaia. The public sector is not present in 11 regional sectors, 8 of which are islands. These include the island of Mykonos, which however shows the second highest number of MUs per 100,000 population due to the private sector presence.

A comparison has been made between the present data at the time of the research (2021) and that of 2017 (**Fig. 1b**). The average number of MUs per 100,000 inhabitants has slightly increased from 6.84 to 7.18 (about 5 %) between

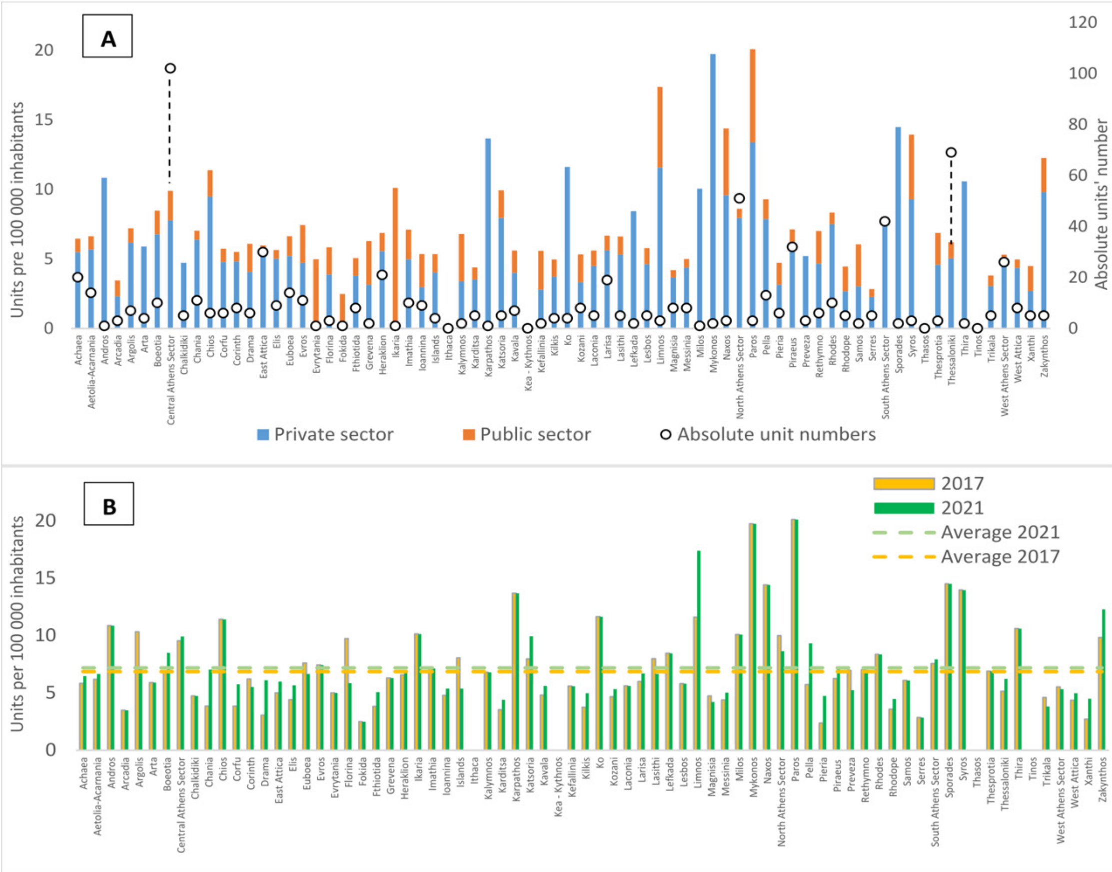

***Fig. 1 (A)** Regional sector distribution of MUs per 100 000 inhabitants, 2021. Private and Public sector bars refer to Units per 100 000 inhabitants and Absolute unit numbers refers to the secondary vertical axis. Source: data from EEAE. **(B)** Regional sector distribution of MUs per 100,000 inhabitants. Comparison between 2017-2021. Source: data from EEAE.*

the years 2017 and 2021. Regions without MU coverage remained the same during this period. The lowest MUs per 100,000 inhabitants' numbers that were observed in 2017 mainly at northeast areas of the country, which lagged behind (Xanthi, Serres, Pieria and Drama), have been largely eliminated, with the regions' numbers being similar to the rest of the country.

The distribution of the four major mammographic technologies is presented next (**Fig. 2a**). Tomosynthesis represents 10% of total units, provided in only 28 regional areas of the country. The dominant technology is digital radiography (DR), covering 46% of the installed units; computed radiography (CR) covers 38%; and about 5% of units are still film based.

Compared to 2017 (Fig. 2b) there is an obvious shift to more modern technologies, with a significant decrease of Film and CR technologies and a subsequent increase in the use of DR and Tomosynthesis technologies. Alongside the modernization of the technologies in use, there is also an increase in the total number of installed MUs of about 7 % over the last four years (from 685 installed units in 2017 to 732 units in 2021).

A comparison is made between Greece and other EU countries in terms of MUs per 100,000 inhabitants (**Fig. 3**). The figure shows clearly that Austria, Belgium, Czech Republic, Denmark, Finland and Sweden have about half the number of MUs operating in Greece. In fact, Greece has the highest number of MUs per 100,000 inhabitants worldwide (6.60), according to OECD [10]. Greece also has the second highest number of MUs per 100,000 females aged between 50-69 (43.8), trailing behind Monaco (59.9), according to WHO's 2014 data [11]. The current number of MUs per 100,000 females aged 50-69 has risen to 56.3, as of 2021 (data from EEAE). This high number of units may be due to the population density of many regions, the large number of small towns and the large number of islands

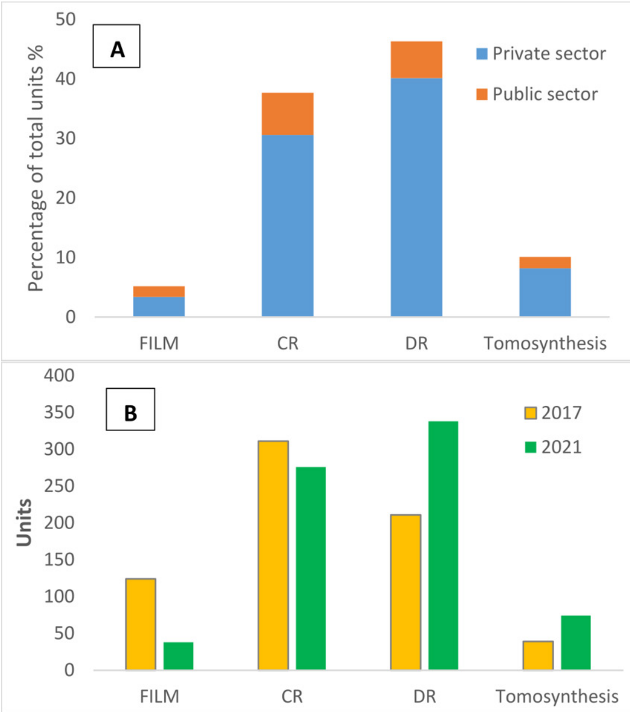

***Fig. 2** Distribution of the four major mammographic technologies. **(A)** Proportional distribution in 2021. **(B)** Comparison of unit distribution between 2017 and 2021. Source: data from EEAE.*

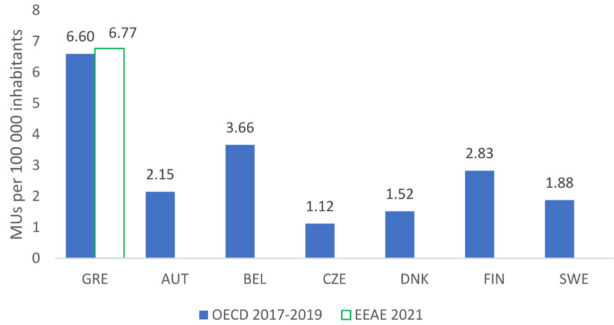

***Fig. 3** Comparison of MUs availability in Greece and similar population EU countries. Adaptation from OECD [10].*

existing in Greece. This implies that a significant number of MUs had to be installed in areas with low populations to assure accessibility. It is indicative that Belgium, Austria and Denmark have much denser populations and smaller distances to medical centres, that raise productivity of the installed technologies compared to Greece.

The Lorenz curves for assessment of the inter-regional distribution equality of MUs are presented next (**Fig. 4a**). The black diagonal line corresponds to complete equity, while the green and yellow curves show the cumulative distribution of MUs in relation to the population percentage for the years 2021 and 2017 respectively. It is clear that both curves slightly deviate from the 45-degree line of equity. Subsequently, the Gini indices are 0.20 for 2017 and 0.16 for 2021. This means that the inequity of distribution was further reduced during the last four years. This can partially be explained by the MUs' regional distribution comparison between 2017 and 2021 (**Fig. 1b**). It can be seen that many regional areas with lower coverage acquired units, thus approaching the country's average number of units per inhabitants.

Finally, we calculated the Lorenz curves using data only from mainland Greece and the islands of Rhodes and Crete, while excluding the small islands, to examine the effect of isolated and sparsely inhabited regions in the MU distribution equality (**Fig. 4b, 4c**). Both curves deriving from the whole dataset deviate greater from the absolute equity line, compared to the curves derived from mainland Greece data only. The corresponding Gini coefficient values were found almost equally reduced: from 0.20 to 0.18 for 2017 and from 0.16 to 0.14 for 2021. This shows that there is an increased homogeneity in the distribution of MUs for both cases, but the difference between mainland Greece and the islands, remains the same.

4. Discussion

During the last four years (2017 to 2021) the MUs distribution inhomogeneities have been reduced throughout the country, with the numbers of units per 100,000 population in low prior coverage areas having risen to approach the country average, resulting in the subsequent decline of inequity. Furthermore, the country average itself is slightly on the rise with more units being installed. The latter comes along with an apparent modernization of the units in use, with the obsolete technologies of film and CR imaging being replaced by DR imaging and Tomosynthesis.

Greece has the highest number of mammography units per 100,000 inhabitants worldwide according to OECD [10]. In a systematic review study by Dafni, Tsourti and Alatsathianos [12] it is shown that the age-standardized female breast cancer incidence rate in Greece was 122.3 per 100,000, compared to the mean value of 144.9 for the EU28 countries (data from the European Cancer Information System, ECIS). Moreover, the mortality age-standardized rate was 32, compared the 32.9 per 100,000 population for

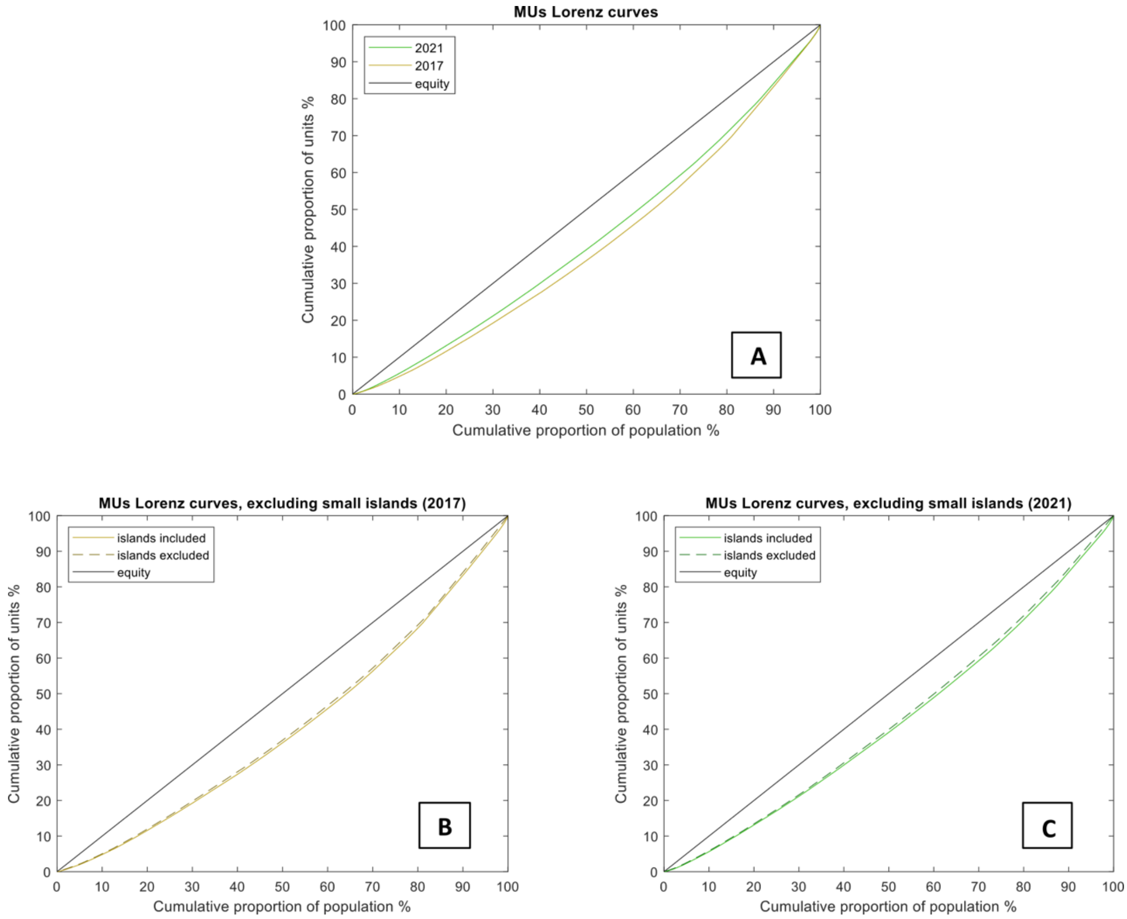

Fig. 4 *MUs Lorenz curves.* ***(A)*** *Comparison between 2017 and 2021.* ***(B)*** *Modification when excluding small islands from the analysis, 2017.* ***(C)*** *Modification when excluding small islands from the analysis, 2021.*

the EU28 countries. The latter is very close to the figures provided by the OECD stats with a mortality rate of 33.7 per 100,000 in Greece to the European average value of 34.1 [13]. Early detection and five-year survival rates are not available for Greece, as opposed to other countries, neither on the CONCORD global cancer survival surveillance program, nor on the OECD databases from 2000 to 2020. However, increasing trend in breast cancer incident rates in Greece from 1990 to 2015 is reported [12], which can be attributed to imaging technology advancements, as well as to wider distribution and access to mammograms.

Even though the MUs' density shows considerable variation across the country, their number is considered well above what would be necessary according to the screening recommendations. It is worth noting that insufficient experience in the interpretation of mammograms for optimal sensitivity and specificity can be an undesirable consequence regarding high numbers of MUs. Despite technological improvements, high error rates in the forms of false negatives and false positives still exist. According to Ekpo et al. [14] approximately 1 to 3 cancer cases are missed by radiologists, while 80% of women recalled for further examinations have normal outcomes, with a high percentage of biopsies having benign results. Most of the missed cases go unnoticed or are misdiagnosed as benign, albeit being visible and examined, due to wrong perception and decision-making [14]. Hence, the existence of a disproportionate number of MUs compared to skilled decision makers can have undesirable consequences regarding screening.

Moreover, higher frequency and broadening of age ranges in which mammography is performed can lead to increased costs and non evidence-based therapies. According to Eurostat, Greece is top of the list with nearly 38 % of women under 50 years old having undergone mammographic screening [15]. The European Commission Initiative on Breast Cancer (ECIBC) recommendations for screening include biennial screening for women aged 50-69 and triennial screening for women 70-74 years old, with an average breast cancer risk. In addition, there is a conditional recommendation with moderate to low evidence certainty, regarding the screening of women between 45-49 years every two to three years [16]. According to the International Agency for Research on Cancer (IARC) there is limited evidence that mammography screening reduces breast cancer mortality in women 40-49 years of age [17]. Additionally, the American College of Physicians has issued a guideline statement that the potential harms outweigh the benefits in most women aged 40 to 49 years [18]. In contrast, other organizations support the broadening of age ranges for breast cancer screening for women with average risk. For example, the American Cancer Society (ACS) suggests that women aged 40 to 44 years should have the choice to start breast cancer screening once a year with mammography if they wish to do so. They also state that women aged 45 to 49 years should be screened with mammography annually [19]. All in all, the risks of screening over the benefits should be considered based on the individual before making a decision.

It is also worth noting that screening recommendations differ among different populations at risk for breast cancer. For example, women who are at high risk for breast cancer based on certain factors should get a breast MRI and a mammogram every year, typically starting at age 30, according to ACS. The factors that may categorize a woman as high risk for developing breast cancer include family history, known BRCA1 or BRCA2 gene mutation of themselves or first-degree family member, prior radiation therapy and specific syndromes [20].

In a study by Autier and Ouakrim [21], the number of MUs in 31 European, North American and Asian countries where significant mammography activity has existed for over 10 years was assessed, collecting data on the number of such units and that of radiologists, by contacting institutions in each country likely to provide the relevant information. In the early 2000's, there were 32,300 units in these countries with the number of MUs ranging from less than 25 to more than 80 per million women, Greece being in the upper limit. [22] Despite that, this excess in available technology is not reflected in the number of mammograms performed, as could be expected.

According to an extensive study performed by INBIT under a WHO agreement [3], the evolution of the number of mammograms and the associated reimbursement costs over the economic crisis period, from 2013 to 2016, demonstrated an overall significant decrease (40%) with the total number of mammograms reimbursed by EOPYY falling by almost 40% from 830,384 to 500,655. Additionally, it is important to notice that in 2013, only 12% of mammograms were performed in the public sector, while by 2016 this share had increased to 26%. As far as regional findings are concerned, the distribution of mammograms per 1,000 inhabitants per regional sector in 2016 revealed big differences amongst regions, according to same study based on data from EOPPY. It is remarkable that, in spite of equipment availability, there is a big divergence in the number of mammograms performed, and subsequently the women participation in the preventive screening programmes across various regions. In particular, Central Greece and North Aegean Sea, lag substantially behind the other regions.

International recommendations and guidelines on the ages and frequency at which mammographic exams should be performed have become quite controversial. There is uncertainty about the magnitude of overdiagnosis, associated with different screening strategies and partly attributable to lack of consensus on estimation methods. It is also noted that 43% of the total MUs installed are using the superseded or outdated technologies of film or CR imaging. Compared to the more modern DR technology, the CR was found to fail in the imaging of malignant calcification clusters and benign lesions in some cases, resulting in reductions in cancer cases detected of 22% and 15%, respectively [23, 24, 25].

5. General conclusions

Uneven geographical distribution of imaging technologies is an issue in many EU countries, resulting in inequalities in access for the inhabitants of rural or remote areas. Having a large number of islands and mountainous areas that are difficult to access, health-care delivery is in general a major concern in Greece. According to the findings on the mammography units covered in this study, the installed base in Greece is well above the European average. However, coverage is still non-existent particularly in some Aegean Sea islands.

There is generally a moderate to low inequality of inter-regional medical equipment distribution, as shown by the Gini coefficients for the MUs. The total increase of units generally would give an intuitive thought that it should reduce the inequality; this statement holds true for the case examined in this paper, although further research should be made before reaching conclusions. The fact that a slight proportional growth of MUs resulted in an inequity decline indicates that strategical planning of medical equipment distribution is a significant factor for making healthcare technologies more accessible to the public.

Lack of a continuously updated inventory means that there are no centrally available data concerning medical equipment in general. Although well-structured and publicly available, the EEAE database on medical radiation installations provides information only regarding licensing and radiation safety purposes, and information on quality control, age and actual use of devices is not available, so the overall picture is not complete. The lack of additional information prevents calculation of critical indicators, as for example the median age of installed equipment. The average age of these devices is higher than the optimum, as indicated by estimations based on supplementary sources. However, the replacement of older equipment and shift to more modern technologies is a recurring pattern for MUs in the last years.

Finally, the public sector lacks a well-defined strategic planning for investment in new technologies, along with evidence-based and transparent decision making. On the other hand, market analysis and stable state policy assumptions, though not being the case in the period covered by this study, are the base on which the private sector follows its own approaches. **R**

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Conflict of interest
The authors declared no conflicts of interest.

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