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Budget impact analysis of implementing a lung cancer screening in high-risk population in Spain

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A B S T R A C T

Objective: To analyze the cost of implementing a population-based lung cancer screening program using low-dose radiation computed tomography (CT) in a high-risk population in Spain.
Method: A budget impact analysis (5 years) was performed from the National Health System' perspective, comparing 16 hypothetical scenarios with screening, based on different age ranges and screening frequencies (annual/biennial), with the current scenario without a lung cancer screening program. Diagnosis, treatment and follow-up costs were considered, as well as the screening costs in the hypothetical scenarios (measured in Euros 2024). From the resident population (50-80 years), the target population and the CT scanners needed to cover the program's demand were calculated. A one-way deterministic sensitivity analysis was performed.
Results: The gross budget impact was estimated at €1708.19 million for the current scenario. Among the hypothetical scenarios, it can range from €3737.17 million (biennial screening, 55-65 years) to €10 009.54 million (annual screening, 50-80 years), resulting in a net budget impact of €2028.98-€8301.35 million. By acquiring 100% of the necessary scanners, the investment reached approximately 22% of the annual program's own costs in the first year. The net impact could be reduced to €1858-€7519 million, for 0% acquisition.
Conclusions: Implementing a lung cancer screening program would generate a high cost for the Spanish National Health System, amounting more than one billion Euros compared to the scenario without screening.

Análisis del impacto presupuestario de implementar un cribado de cáncer de pulmón en población de alto riesgo en España

Palabras clave:
Detección temprana del cáncer
Neoplasias pulmonares
Análisis de impacto presupuestario
Programas de cribado
Programas de salud nacionales
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R E S U M E N

Objetivo: Analizar el coste de un programa de cribado de cáncer de pulmón mediante tomografía computarizada (TC) de baja dosis de radiación en población de alto riesgo en España.
Método: Se realizó un análisis de impacto presupuestario (5 años) desde la perspectiva del Sistema Nacional de Salud, comparando 16 escenarios hipotéticos de cribado (diferentes rangos de edad y frecuencias de cribado anual o bienal) con el escenario actual sin cribado. Se consideraron los costes de diagnóstico, tratamiento y seguimiento, así como los costes del cribado en los escenarios hipotéticos (euros de 2024). Se estimaron la población diana y los equipos de TC necesarios para el programa. Se realizó un análisis de sensibilidad.
Resultados: El impacto presupuestario bruto se estimó en 1708,19 millones de euros (M€) para el escenario actual. En los escenarios hipotéticos, puede oscilar entre 3737,17 M€ (cribado bienal, 55-65 años) y 10.009,54 M€ (cribado anual, 50-80 años), suponiendo un impacto presupuestario neto de 2028,98-8301,35 M€. Adquiriendo el 100% de los escáneres necesarios, la inversión alcanzaría aproximadamente el 22% de los costes anuales propios del programa (año 1). El impacto neto podría reducirse a 1858-7519 M€ para una adquisición del 0%.

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Conclusiones: Implantar un programa de cribado de cáncer de pulmón generaría un coste elevado para el Sistema Nacional de Salud español, superior a los 1000 millones de euros respecto al escenario sin cribado.

Introduction

Lung cancer (LC) is a malignant growth of cells in the lung or bronchial system. The symptoms of LC are nonspecific and usually appear when the disease has already spread, making early diagnosis difficult. LC is the fourth most common type of cancer in Spain and, in terms of mortality, it is the leading cause of cancer death, responsible for more than 23,000 deaths in 2023 (20.6% of total cancer mortality).[1] Although there are several risk factors of developing LC, tobacco addiction is by far the most important preventable cause of LC, responsible for 90% of cases in men and 80% in women.[2] Passive smoking or exposure to tobacco smoke in non-smokers increases the risk by 20-30% compared to non-smokers not exposed to passive smoke.[3]

A screening test that detects the disease at an early stage would help modify the clinical course of the disease, facilitating early diagnosis and treatment, thereby improving survival by preventing disease progression. Imaging techniques are used for screening, with low-dose radiation computed tomography (LDCT) being the only test currently recommended. Overall, the LC screening with LDCT may have a benefit in LC-specific mortality compared to no screening, but the benefit in overall mortality and morbidity is inconclusive.[4] In economic terms, many studies conclude that screening with LDCT is more expensive and more effective than no screening, but it could be cost-effective only under certain conditions.[4,5] The use of blood or exhaled air biomarker panels is also proposed, although they are in an early phase of development and validation.

Early detection of LC using LDCT is increasingly being implemented as a population screening program, although there is still some uncertainty about its risk-benefit ratio and cost-effectiveness. In this context, a budget impact analysis was carried out to 1) estimate the cost of its implementation in high-risk population for the National Health System (NHS) in Spain, and 2) provide useful methods for other researchers and decision-makers considering the implementation of LC screening in their healthcare settings.

Method

Interventions and target population

We estimated the gross budget impact of several hypothetical scenarios, in which different target population groups according to age participate in a national screening program, and the current scenario in Spain (without a LC screening program), where LCs are diagnosed through the appearance of symptoms or in check-ups. The frequency of the screening can be annual or biennial.

The target population considered in all scenarios was the Spanish population between 50 and 80 years, because this range covers the ages at which LC is diagnosed in a greater proportion: almost the 60% of cases are identified between 55 and 74 years.[6]

In the screening scenarios, different age intervals for screening were evaluated: 50-65, 50-70, 50-75, 50-80, 55-65, 55-70, 55-75, and 55-80 years, according to the recommendations for screening included in clinical practice guidelines. All Spanish residents within the age range receive an invitation letter to contact primary care, but only the high-risk population confirmed by nursing (i.e., smokers who consume at least 20 pack-years or ex-smokers who have stopped smoking in the last 15 years and with the same consumption) is eligible for screening. This approach was chosen because identifying the high-risk population is a real challenge, as individual information on high-risk criteria is currently unavailable to the NHS.

The analysis focused on (ex-)smoker population due to limited evidence on the effectiveness of LC screening in people with risk factors other than smoking. Furthermore, the aforementioned high-risk criteria were established to cover the broadest possible population, based on randomized clinical trials evaluating the effectiveness of the screening program. Universal screening was not considered, following recommendations of clinical practice guidelines. This is based on evidence gathered elsewhere.[4]

Perspective and time horizon

We only evaluated the direct health costs (Spanish NHS perspective), generated in the first five years of the implementation. The costs included in the current scenario were the costs of diagnosis, treatment and follow-up, while the hypothetical scenarios included, in addition to the previous ones, the costs of screening (Table A1 of the Appendix A). Costs were expressed in Euros of 2024, and no discount rates were applied.[7] Costs obtained from regional official gazettes were no converter to 2024, regardless of the publication year, because if a more recent gazette is not available, the cost still applies.

Cost estimation in the current scenario (without LC screening program)

The population that generates each considered cost was estimated. In the scenario without a screening program, the percentage of people diagnosed with LC annually (Table A2 of the Appendix A) was calculated by dividing the annual incidence of LC in Spain, in 2024,[1] by the resident Spanish population aged between 50 and 80 years old in the same year.[8] These percentages were assumed to be the same for all ages between 50 and 80 years, as age-specific data were unavailable.

We also estimated the LC by cancer stages, applying the percentages of Table A3 of the Appendix A, and the population who received each treatment per stage, from the distribution of Table A4 of the Appendix A. We assumed that people with LC in stages I-IIIB go to primary care due to the presence of symptoms, while those with a LC in stage IV go to the emergency room, where they are diagnosed. Diagnosis requires several tests (bronchoscopy, chest X-ray, positron emission tomography, laboratory test and electrocardiogram) and two visits to the pulmonologist for history, examination and diagnosis. The costs of the current scenario were estimated by multiplying the diagnosed population, divided by cancer stages, by unit costs of diagnosis, and treatment and follow-up shown in Table A1 of the Appendix A.

Cost estimation in the hypothetical scenarios (with LC screening program)

In the scenarios with a LC screening program, the entire resident population, who meets the age criterion (i.e., belonging to the age range of the specific hypothetical scenario), is invited to contact primary care to determine their eligibility. All residents are invited in the first year, while in subsequent years, the invited population are 1) those who received the initial invitation but did not participate in the screening and were not diagnosed with LC outside of the screening program (and still meet the age criterion), and 2) those who joint, in the current year, the established age range. The total relative cost of the invitation to the screening program was estimated by multiplying the invited population each year by the unit cost of a post-code letter. It is assumed that 70% of the invited population initially respond and have a telephone consultation with primary care nursing (with its respective cost to the Spanish National Health Survey [SNHS]) to confirm compliance with the criteria of high-risk population for developing LC. The percentage of the population at high risk (Table A5 of the Appendix A) has been calculated from the SNHS 2011-2012,[9] the last national health survey with this information.

Regarding participation, at the time of this analysis, there was no information available on participation figures for LC screening in Spain, as it has not been yet implemented in this country. Therefore, the participation rates of the national colorectal cancer screening program were taken as a reference, because it is the only program in Spain including men and women with similar age intervals to those used in this analysis. We assumed an initial participation rate for first round of 30% in the first year, which increases in 10.8%, 28.7% and 10.3% in the second, third and fourth years, respectively.[10] For the fifth year, we assumed the same increase as in the fourth. Data are taken from 2007-2009 because they are the initial years of the colorectal cancer program in which there is data for more than two regions. People who did participate in the screening in the first round and have not been diagnosed with LC will be screened again the following year (annual screening) or in two years (biennial screening), with a participation rate of 100%. All participants receive a SMS as an appointment reminder, at an additional cost to the NHS (Table A1 of the Appendix A).

The number of LDCT performed annually corresponds to the amount of the population participating each year, plus an additional 9.2% due to indeterminate results that require repeating the test.[11] The cost of participating in the screening program is derived from the LDCT unit cost (Table A1 of the Appendix A) and the total number of LDCT performed (including the repeated tests). Horeweg et al.[12] determined that 2.3% of LDCT reflect a positive result (true-positive or false-positive), for which the diagnostic procedure must be continued with confirmatory tests (bronchoscopy, chest X-ray, positron emission tomography, laboratory test and electrocardiogram) and two visits to the pulmonologist. In this case, the associated costs were estimated by multiplying the unit costs related to the diagnosis (confirmatory tests and pulmonology visits; Table A1 of the Appendix A) by the population with a positive result. They also calculated a positive predictive value of 40.4%, which allowed estimating the diagnosed LC through the screening strategy. The number of LC by stages was estimated from the percentages of Table A3 of the Appendix A.

In the hypothetical scenarios, diagnoses also can occur outside of the screening program, due to the appearance of symptoms or other check-ups, for the population that does not participate in the program (due to selection criteria or own decision). The diagnosis costs generated in these cases are calculated as in the current scenario. As well, after diagnosis (through the screening or not) patients were treated (Table A4 of the Appendix A), with their respective costs of treatment and follow-up (Table A1 of the Appendix A).

Regarding the number of CT scanners needed to be acquired, it was calculated by dividing the number of LDCT performed each year by the annual capacity of each equip. This latter variable was estimated assuming an average of 48 patients per CT scan equip per working day[13] and 249 working days per year ($= 365\ days - 104\ days\ (weekends) - 12\ holidays\ (on\ average\ in\ Spain)$), each equip can annually performs 11,952 LDCT ($= 48\ patients/equip/day \times 249\ working\ days$). Given the capacity of the CT scanners available in the NHS for covering the LDCT demand of the screening program is unknown, we assumed the purchase of the 100% of the necessary equipment, which would be progressive depending on the needs of each year. The unit cost of a CT scanner was extracted from Ruano-Ravina et al.,[13] due to the scarcity of available information on CT scanner prices.

The radiologist costs were based on the invested time to prepare reports (including the interpretation of the tomography), which was estimated at 0.57 hours/report, by assuming that a radiologist can complete 13.92 reports in an 8-hour shift.[14] By multiplying the annual LDCTs by the average time spent per report, the annual time required by radiologists was obtained. In monetary terms, the labour cost by effective hour of the division 86 (“Human Health activities”, according to the statistical classification of economic activities in the European Community (NACE-09)) was used (€32.84, average of the quarters of 2024).[15]

Budget impact analysis

The gross budget impact of each scenario was estimated by summing the costs of diagnosis, treatment and follow-up, and adding the costs of screening in the hypothetical scenarios. Results are shown in annual terms and for the full time horizon (5 years).

The difference in the gross budget impact between each hypothetical scenario and the current scenario results into the net budget impact of the implementation of the program.

The net impact by regions was also estimated. For the regional budget impact, the resident population and the LC incidence in each region are considered (Table A2 of the Appendix A). The proportion of the population at high-risk of LCs used in the regional analysis was the national one, given the insufficient size of the regional samples in the SNHS 2011-2012 to obtain this data disaggregated by age and region.

Sensitivity analysis

Finally, a one-way deterministic sensitivity analysis was performed to evaluate how variations in the following key parameters affect the results: response rate, participation (for the first round) rate, percentage of positive result, positive predictive value, unit cost of the CT scanner, unit cost of the LDCT, and percentage of CT scanners to be acquired. Values used in the sensitivity analysis can be found in Table A6 of the Appendix A.

Results

The analysis performed allowed us to estimate not only the net budget impact of implementing a LC screening program in Spain, but also the potential number of people diagnosed by cancer stage in each scenario (Table B1 of the Appendix B). Overall, the screening program, especially the annual one, could diagnose more people than the current scenario without screening. In addition, 40-56% (annual screening) and 32-50% (biennial screening) of diagnoses are detected at stage I, whereas in the no-screening scenario, 52% of diagnoses are detected at stage IV. Notably, biennial screening would detect almost the same number of stages I (32%) and IV (35%) cancers when the age interval is specified as 55-65 years.

The gross budget impact for the current scenario (without screening) is estimated at €1708.19 million in five years (Table 1). Meanwhile, the budget impact of the implementation of a LC screening program varies depending on the established age range delimiting the target population. Among the hypothetical scenarios (with screening), the total gross budget impact can range between €3737.17 million (biennial screening, 55-65 years) and €10 009.54

Table 1
Gross and net budget impact for Spain (millions of Euros).

Age interval[a]	Year	Gross budget impact			Net budget impact (vs. no screening)	
		Current scenario (no screening)	Hypothetical scenarios		Annual screening	Biennial screening
			Annual screening	Biennial screening		
50-65	1	327.13	893.12	893.12	565.99	565.99
	2	334.42	1143.34	746.95	808.92	412.53
	3	341.80	1437.68	1144.87	1095.88	803.07
	4	348.92	1668.43	886.58	1319.51	537.66
	5	355.92	1875.73	1092.42	1519.81	736.50
	Total	1708.19	7018.29	4763.93	5310.10	3055.74
50-70	1	327.13	1012.11	1012.11	684.98	684.98
	2	334.42	1325.18	835.24	990.76	500.82
	3	341.80	1695.61	1333.76	1353.81	991.96
	4	348.92	1997.62	1004.02	1648.70	655.10
	5	355.92	2268.01	1276.97	1912.09	921.05
	Total	1708.19	8298.53	5462.10	6590.34	3753.92
50-75	1	327.13	1105.90	1105.90	778.77	778.77
	2	334.42	1463.04	904.89	1128.62	570.47
	3	341.80	1889.17	1478.17	1547.37	1136.37
	4	348.92	2243.76	1097.12	1894.84	748.20
	5	355.92	2562.59	1419.66	2206.67	1063.74
	Total	1708.19	9264.46	6005.73	7556.27	4297.55
50-80	1	327.13	1178.32	1178.32	851.19	851.19
	2	334.42	1570.65	961.10	1236.23	626.68
	3	341.80	2038.98	1588.90	1697.18	1247.10
	4	348.92	2431.48	1169.88	2082.56	820.96
	5	355.92	2790.10	1533.14	2434.18	1177.22
	Total	1708.19	10 009.54	6431.34	8301.35	4723.15
55-65	1	327.13	704.73	704.73	377.60	377.60
	2	334.42	868.44	610.13	534.02	275.71
	3	341.80	1059.16	867.86	717.36	526.06
	4	348.92	1204.79	711.62	855.87	362.70
	5	355.92	1333.04	842.83	977.12	486.91
	Total	1708.19	5170.15	3737.17	3461.97	2028.98
55-70	1	327.13	823.72	823.72	496.60	496.60
	2	334.42	1050.28	698.42	715.86	364.00
	3	341.80	1317.85	1056.75	976.05	714.95
	4	348.92	1533.22	829.06	1184.30	480.14
	5	355.92	1725.31	1026.62	1369.40	670.71
	Total	1708.19	6450.39	4434.58	4742.20	2726.39
55-75	1	327.13	917.51	917.51	590.38	590.38
	2	334.42	1188.14	768.07	853.72	433.65
	3	341.80	1510.65	1201.16	1168.85	859.36
	4	348.92	1780.12	922.16	1431.20	573.23
	5	355.92	2019.89	1169.32	1663.98	813.40
	Total	1708.19	7416.32	4978.21	5708.13	3270.02
55-80	1	327.13	989.93	989.93	662.80	662.80
	2	334.42	1295.75	824.28	961.33	489.86
	3	341.80	1661.22	1311.89	1319.42	970.09
	4	348.92	1967.08	994.92	1618.16	646.00
	5	355.92	2247.41	1282.79	1891.49	926.87
	Total	1708.19	8161.40	5403.81	6453.21	3695.63

[a] The population considered in the analysis is those aged 50-80 years old. The age ranges only refer to the susceptible population to being screened in the hypothetical scenarios.

million (annual screening, 50-80 years), resulting in a net budget impact between 2028.98 million and 8301.35 million of additional Euros in the first five years of the implementation (Table 1).

Disaggregating the gross budget impact by cost groups reveals higher expenditures across all categories in the hypothetical scenarios (Tables B2 and B3 of the Appendix B). The costs of treatment and follow-up represent the largest item (81% of the total impact) in the scenario without screening, while in the hypothetical scenarios the highest costs are those classified as screening costs (44%-62% of the total gross budget impact) (Table 2). If we do not consider the latter in the screening scenarios, the weight of the treatment and follow-up costs on the total impact is lower in the scenarios with screening than in the scenario without screening (56%-70% vs. 81%, respectively) (Table 2). Additionally, within the screening cost group, LDCT and nursing consultation components show the higher percentages (i.e., 53–59% and 14–21% of total screening costs, respectively) (Tables B2 and B3 of the Appendix B).

Regarding investment in CT scanners, the implementation of the screening requires a large investment in new equipment (Table 3). Assuming the acquisition of 100% of the necessary equips, the investment can range from €314.72 million and €781.85 million (screening between 55-65 years old (the shortest age range) and 50-80 years old (the widest age range), respectively) in the annual screening. In the case of biennial screening, the investment can vary between €170.7 million and €417.6 million (for the shortest and the widest age range, respectively). Also, given that the implementation would be progressive, the investment in the first year would be the highest in relative terms (approximately 22% of the screen-

Table 2
Gross budget impact for Spain disaggregated by cost groups (millions of Euros).

Age interval[a]	Cost group	No screening€ (%)	Annual screening			Biennial screening		
			€	%	% (without screening costs)	€	%	% (without screening costs)
50-65	Screening	0 (0%)	3950.77	56%	-	2489.27	52%	-
	Diagnosis	325.03 (19%)	1187.32	17%	39%	780.89	16%	34%
	Treatment and follow-up	1383.16 (81%)	1880.2	27%	61%	1493.78	31%	66%
	Total	1708.19 (100%)	7018.29	100%	100%	4763.93	100%	100%
50-70	Screening	0 (0%)	4903.99	59%	-	3065.85	56%	-
	Diagnosis	325.03 (19%)	1395.01	17%	41%	884.31	16%	37%
	Treatment and follow-up	1383.16 (81%)	1999.52	24%	59%	1511.94	28%	63%
	Total	1708.19 (100%)	8298.53	100%	100%	5462.1	100%	100%
50-75	Screening	0 (0%)	5627.25	61%	-	3515.95	59%	-
	Diagnosis	325.03 (19%)	1549.15	17%	43%	962.9	16%	39%
	Treatment and follow-up	1383.16 (81%)	2088.06	23%	57%	1526.88	25%	61%
	Total	1708.19 (100%)	9264.46	100%	100%	6005.73	100%	100%
50-80	Screening	0 (0%)	6189.12	62%	-	3871.42	60%	-
	Diagnosis	325.03 (19%)	1665.48	17%	44%	1022.1	16%	40%
	Treatment and follow-up	1383.16 (81%)	2154.93	22%	56%	1537.81	24%	60%
	Total	1708.19 (100%)	10009.54	100%	100%	6431.34	100%	100%
55-65	Screening	0 (0%)	2577.36	50%	-	1648.38	44%	-
	Diagnosis	325.03 (19%)	886.37	17%	34%	627.22	17%	30%
	Treatment and follow-up	1383.16 (81%)	1706.42	33%	66%	1461.57	39%	70%
	Total	1708.19 (100%)	5170.15	100%	100%	3737.17	100%	100%
55-70	Screening	0 (0%)	3530.59	55%	-	2224.2	50%	-
	Diagnosis	325.03 (19%)	1094.06	17%	37%	730.65	16%	33%
	Treatment and follow-up	1383.16 (81%)	1825.74	28%	63%	1479.73	33%	67%
	Total	1708.19 (100%)	6450.39	100%	100%	4434.58	100%	100%
55-75	Screening	0 (0%)	4253.84	57%	-	2674.3	54%	-
	Diagnosis	325.03 (19%)	1248.2	17%	39%	809.23	16%	35%
	Treatment and follow-up	1383.16 (81%)	1914.28	26%	61%	1494.68	30%	65%
	Total	1708.19 (100%)	7416.32	100%	100%	4978.21	100%	100%
55-80	Screening	0 (0%)	4815.72	59%	-	3029.77	56%	-
	Diagnosis	325.03 (19%)	1364.53	17%	41%	868.44	16%	37%
	Treatment and follow-up	1383.16 (81%)	1981.15	24%	59%	1505.61	28%	63%
	Total	1708.19 (100%)	8161.4	100%	100%	5403.81	100%	100%

Percentages were estimated with respect to the total cost in each age range.
[a] The population considered in the analysis is those aged 50-80 years old. The age ranges only refer to the susceptible population to being screened in the hypotheticalscenarios.

ing costs of that year, both in annual and biennial programs; results not shown).

The net budget impact by regions (Table 4) would be greater in those regions where the population susceptible to be screened is larger (i.e., Andalusia, Catalonia and Madrid), assuming equal costs for the entire national territory. However, this impact could be undervalued in the regions that, with a smaller target population, could not obtain volume discounts for CT scanner purchase.

The sensitivity analysis shows how, in general, the most relevant variations in the net budget impacts are observed when the response rate and the participation rate are modified (Figures C1 and C2 of the Appendix C). Also, when the percentage of positive LDCT increases from 2.3% to 5.7% (value estimated from Field et al.[16]), generating an increase of 48%-50% of the net impacts.

There is a large uncertainty surrounding the necessary number of CT equipment to be acquired. However, varying this parameter would not significantly affect the net budget impact. In fact, it could range between €1.9 and €7.9 billion, considering all screening scenarios (Figures C1 and C2 of the Appendix C). Specifically in the case of not acquiring any CT equipment, the net impact of an annual program would be €3.2 billion for the shortest age range (55-65 years) and €7.5 billion for the widest range (50-80 years), while the net impact of a biennial program would be €1.9 billion or €4.3 billion, respectively.

Discussion

In healthcare decision-making, a budget impact analysis offers practical short- and medium-term budget impact projections that are crucial for resource planning. These projections should be considered alongside cost-effectiveness results when evaluating the introduction of a new health technology into the NHS.

Here, we present such projections in the context of a population-based LC screening program by evaluating several hypothetical scenarios based on different age ranges and screening frequencies. Our findings indicates that, regardless the hypothetical scenario considered, the program would entail a substantial cost for the NHS, consistent with the conclusions of Ruano-Ravina et al.[13]

The own costs generated by the screening program (i.e., screening costs in Table A1 of the Appendix A) represent the largest contribution to the total gross budget impact. Within this cost group, although the LDCT and nursing consultations are the main cost components, accounting for over 70% of the share, the investment in CT scan equipment constitutes a large part: around 11%-12% of the screening costs are due to the acquisition of new equipment (assuming the purchase of 100% of the equipment needed). Reducing the number of CT scanners purchased would not greatly affect the net impact: it may be reduced by only 5%-9% if the share of CT scanners purchased is reduced to 50% or 0%, respectively; however, it is noteworthy that given the estimated useful

Table 3
Investment in computed tomography scanners in each hypothetical scenario.

Age interval[a]		Annual screening					Biennial screening				
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5
50-65	LDCT done (millions)[b]	1.67	3.21	4.90	6.38	7.68	1.67	1.65	3.37	2.96	4.10
	Required CT scan equips[c]	140	269	411	534	643	140	139	282	248	343
	Acquired CT scan equips[d]	140	129	142	123	109	140	0	142	0	61
	Annual CT scan equip investment (millions €)	106.69	98.30	108.21	93.73	83.06	106.69	0	108.21	0	46.48
	Total investment in 5 years, € (%[e])	489 991 720 (12.4%)					261 379 720 (10.5%)				
50-70	LDCT done (millions)[b]	2.00	3.92	6.04	7.95	9.66	2.00	1.99	4.14	3.64	5.14
	Required CT scan equips[c]	168	328	506	666	809	168	167	347	305	431
	Acquired CT scan equips[d]	168	160	178	160	143	168	0	179	0	84
	Annual CT scan equip investment (millions €)	128.02	121.93	135.64	121.93	108.97	128.02	0	136.41	0	64.01
	Total investment in 5 years, € (%[e])	616 490 360 (12.6%)					328 439 240 (10.7%)				
50-75	LDCT done (millions)[b]	2.26	4.44	6.89	9.12	11.13	2.26	2.24	4.72	4.15	5.94
	Required CT scan equips[c]	189.00	372.00	577.00	764.00	932.00	189.00	188.00	396.00	348.00	497.00
	Acquired CT scan equips[d]	189.00	183.00	205.00	187.00	168.00	189.00	0.00	207.00	0.00	101.00
	Annual CT scan equip investment (millions €)	144.03	139.45	156.22	142.50	128.02	144.03	0.00	157.74	0.00	76.97
	Total investment in 5 years, € (% [e])	710 221 280 (12.6%)					378 733 880 (10.8%)				
50-80	LDCT done (millions)[b]	2.44	4.83	7.53	10.00	12.26	2.44	2.44	5.16	4.54	6.55
	Required CT scan equips[c]	205.00	405.00	630.00	837.00	1.026.00	205.00	204.00	432.00	380.00	548.00
	Acquired CT scan equips[d]	205.00	200.00	225.00	207.00	189.00	205.00	0.00	227.00	0.00	116.00
	Annual CT scan equip investment (millions €)	156.22	152.41	171.46	157.74	144.03	156.22	0.00	172.98	0.00	88.40
	Total investment in 5 years, € (%[e])	781 853 040 (12.6%)					417 597 920 (10.8%)				
55-65	LDCT done (millions)[b]	1.12	2.13	3.21	4.13	4.93	1.12	1.11	2.21	1.97	2.67
	Required CT scan equips[c]	94.00	178.00	269.00	346.00	413.00	94.00	93.00	185.00	166.00	224.00
	Acquired CT scan equips[d]	94.00	84.00	91.00	77.00	67.00	94.00	0.00	91.00	0.00	39.00
	Annual CT scan equip investment (millions €)	71.63	64.01	69.35	58.68	51.06	71.63	0.00	69.35	0.00	29.72
	Total investment in 5 years, € (%[e])	314 722 520 (12.2%)					170 696 960 (10.4%)				
55-70	LDCT done (millions)[b]	1.45	2.83	4.35	5.71	6.91	1.45	1.45	2.98	2.65	3.71
	Required CT scan equips[c]	122.00	237.00	365.00	478.00	579.00	122.00	122.00	250.00	222.00	311.00
	Acquired CT scan equips[d]	122.00	115.00	128.00	113.00	101.00	122.00	0.00	128.00	0.00	61.00
	Annual CT scan equip investment (millions €)	92.97	87.63	97.54	86.11	76.97	92.97	0.00	97.54	0.00	46.48
	Total investment in 5 years, € (%[e])	441 221 160 (12.5%)					236 994 440 (10.7%)				
55-75	LDCT done (millions)[b]	1.71	3.35	5.20	6.88	8.39	1.71	1.70	3.57	3.16	4.50
	Required CT scan equips[c]	143.00	281.00	435.00	576.00	702.00	143.00	143.00	299.00	265.00	377.00
	Acquired CT scan equips[d]	143.00	138.00	154.00	141.00	126.00	143.00	0.00	156.00	0.00	78.00
	Annual CT scan equip investment (millions €)	108.97	105.16	117.35	107.45	96.02	108.97	0.00	118.88	0.00	59.44
	Total investment in 5 years, € (%[e])	534 952 080 (12.6%)					287 289 080 (10.7%)				
55-80	LDCT done (millions)[b]	1.89	3.75	5.83	7.76	9.51	1.89	1.89	4.00	3.55	5.12
	Required CT scan equips[c]	159.00	314.00	489.00	649.00	796.00	159.00	159.00	335.00	298.00	428.00
	Acquired CT scan equips[d]	159.00	155.00	175.00	160.00	147.00	159.00	0.00	176.00	0.00	93.00
	Annual CT scan equip investment (millions €)	121.16	118.12	133.36	121.93	112.02	121.16	0.00	134.12	0.00	70.87
	Total investment in 5 years, € (%[e])	606 583 840 (12.6%)					326 153 120 (10.8%)				

CT: computed tomography; LDCT: low dose computed tomography.
[a] The population considered in the analysis is 50-80 years old, but the age ranges only refer to the population susceptible to being screened.
[b] Repeated LDCT due to indeterminate results are included.
[c] The number of required CT scan equips were estimated assuming 249 working days per year, 48 patients per CT scan equip per working day and, therefore, 11 952 potential LDCT per CT scan equip.
[d] The difference between required CT scan equips and those already existing in previous years is acquired each year.
[e] Percentage was estimated with respect total screening cost in each age range (Table 2).

life of the CT equipment, this investment (if necessary) would need to be repeated every 10 years.[17]

The results also show how implementing a LC screening program could reduce the weight of the treatment and follow-up costs on the total budget impact, which is in line with previous international results.[18] This may be explained by the lower need for treatments for advanced LC, which are more expensive than those for early stages. The detection of LC in early stages by means of screening program (Table B1 of the Appendix B) could improve the prognosis of the disease by avoiding or delaying the onset of advanced stages.

To the best of our knowledge, this is the first budget impact analysis of the LC screening in Spain comparing 16 hypothetical scenarios with screening. Internationally, Silvestrini et al.[19] estimated a lower incremental five-year impact for a biennial screening for individuals aged 55-74 in Argentina (approximately $129 million), which may be explained by lower unit costs and participations rates, for example. Our estimates are more in line with those

Table 4
Net budget impact by region (millions of Euros).

	Age intervals for the screening							
Region	50-65	50-70	50-75	50-80	55-65	55-70	55-75	55-80
Annual screening								
Andalusia	946.22	1172.76	1336.62	1457.66	623.97	849.74	1013.61	1134.65
Aragón	146.90	183.89	212.22	233.66	96.69	133.69	161.25	183.45
Asturias	118.23	152.15	179.01	200.42	78.82	112.74	139.60	161.01
Balearic Islands	132.54	160.34	181.89	197.83	84.09	111.89	133.43	149.37
Canary Islands	271.06	329.79	372.37	402.69	177.42	235.39	278.73	309.05
Cantabria	67.93	86.03	100.29	110.58	44.85	62.96	77.22	87.51
Castilla y León	269.87	345.65	402.80	447.99	183.61	259.40	316.55	361.73
Castilla-La Mancha	229.81	285.59	324.44	353.36	151.65	207.43	246.28	275.96
Catalonia	841.42	1037.01	1188.84	1308.32	536.78	732.36	884.20	1003.68
Valencia	590.75	734.65	844.07	927.71	385.65	528.80	638.22	721.86
Extremadura	118.83	149.66	171.04	188.35	81.24	112.07	134.22	150.77
Galicia	301.30	381.16	445.82	499.37	198.33	278.20	342.85	396.41
Madrid	746.04	911.11	1036.48	1136.52	475.29	641.13	766.49	865.77
Murcia	165.80	201.93	228.70	247.98	106.56	143.46	169.46	189.50
Navarra	72.57	90.55	103.41	114.52	47.36	64.58	78.20	88.55
Basque Country	246.66	310.75	361.12	401.10	163.28	227.37	276.98	316.96
La Rioja	35.87	44.76	51.60	56.34	23.27	32.15	38.99	44.50
Ceuta	8.12	10.54	11.59	12.25	5.59	7.24	9.06	9.71
Melilla	7.87	10.36	11.39	11.97	5.52	7.25	9.04	9.63
Biennial screening								
Andalusia	545.65	669.42	761.37	830.54	366.39	489.39	581.34	651.27
Aragón	84.51	104.10	119.86	132.80	56.82	76.41	92.17	105.11
Asturias	67.80	86.21	101.57	114.00	45.72	64.90	80.25	91.93
Balearic Islands	76.51	92.03	103.74	113.55	49.50	65.02	76.72	85.77
Canary Islands	156.78	188.80	213.07	230.27	104.46	136.48	160.75	177.95
Cantabria	39.20	49.04	56.99	63.18	26.07	36.67	44.62	50.04
Castilla y León	154.22	194.97	227.05	252.49	106.73	147.49	179.56	205.01
Castilla - La Mancha	132.05	162.05	184.10	200.88	88.87	118.86	140.92	157.70
Catalonia	484.63	591.29	677.48	745.67	314.68	422.10	507.53	575.72
Valencia	341.55	420.29	481.67	529.44	227.12	305.09	367.24	415.00
Extremadura	67.98	84.54	97.23	106.61	47.78	64.34	76.26	85.64
Galicia	172.63	215.83	252.64	282.55	115.64	159.60	195.65	226.32
Madrid	430.50	520.54	591.74	648.28	279.15	369.95	440.39	497.69
Murcia	95.54	115.92	130.90	141.85	62.58	82.96	97.93	108.89
Navarra	41.80	51.14	58.73	65.00	28.25	37.59	45.18	50.68
Basque Country	141.41	176.85	204.56	227.57	95.46	130.14	158.61	180.86
La Rioja	20.82	25.25	29.43	32.15	13.88	19.07	22.49	25.20
Ceuta	5.04	5.93	6.51	6.89	3.61	4.51	5.09	5.47
Melilla	4.90	5.84	6.42	6.75	3.58	4.52	5.10	5.43

from the United States, where annual screening costs exceed $1.3 billion.[20,21] Both Goulart et al.[20] and us determined similar annual costs of the screening program: $1.30 billion for the US, and €1 billion for Spain. To be comparable, this cost for Spain (not included in the results of this paper) refers to the cost of year 1 of an annual screening program for a target population of 55-75 years, with a 50% participation rate and 0% of CT equipment purchased (Goulart et al.[20] set a target population of 55-74 years and a one-year horizon). Despite the possible differences in costs, population characteristics and healthcare system between Spain and the US, the results of the impact of the implementation of a national screening converge in economic figures in both studies.

Our analysis has several limitations. First, the screened population is obtained from some assumptions: 1) the response rate to the screening invitation was based on assumptions; 2) the percentage of high-risk population of developing LC was obtained through the SNHS 2011-12, because it is the last national survey with the data for this calculation; 3) the participation rate was estimated based on the participation in the colorectal cancer screening program in Spain; and 4) the distributions of LC by stage and treatment were calculated from international studies,[12,22] given the scarcity of data for the Spanish population. Additionally, only first-line treatments are considered.

Second, due to the lack of studies for Spain, the effectiveness of LDCT was extracted from the international literature[11,12]. Additionally, data from de Koning et al.[11] refer only to a male population, while the population included in our analysis is made up of both sexes.

Third, the real capacity of the available CT scanners in the Spanish NHS to cover the demand generated by the LC screening program was unknown, so the acquisition of 100% of the necessary CT scanners was assumed. The fewer CT scanners needed, the lower budget impact might be. In contrast, the current budget impact would be underestimated if the CT equipment were not working at full capacity, as we assumed. Also, the costs of maintenance and replacement of CT scanner parts, which were not included in the analysis, will have to be assumed by the NHS. Furthermore, the unit cost of a CT scanner was obtained from the literature.[13]

And fourth, the cost of preventive public interventions (e.g., smoking cessation programmes), which is recommended to be implemented in conjunction with LC screening, were not considered. Their consideration could have a double effect on the gross budget impact of the screening scenarios: 1) it would increase the budget impact by adding the costs of their application, and 2) if these actions were effective, the budget impact could decrease by reducing the target population in long term (smokers and ex-smokers who have been quitting in the last 15 years). Likewise, the cost of potential public campaigns aimed at raising awareness of the benefits of participating in screening programs should be added. Finally, the budget impact would be increased if the costs derived from the diagnosis and treatment of diseases other than LC found incidentally during screening were included.

The results of the budget impact analysis estimated for one organization are not generalizable to another organization. However, the methods applied and described in this article have followed internationally established methods[7] and, therefore, may be helpful for other researchers or economic managers to perform similar analyses when considering implementing LC screening in their settings or countries, especially for European countries with national cancer screening programs and public health systems comparable to the Spanish one. In addition, the greatest utility of this article is to make available to the Spanish regional authorities an instrument adaptable to each of their regions so that, when the time comes to plan the implementation of the screening program, they can make their updated estimations with the data of each organization.

In conclusion, and according to the results, implementing a LC screening program in Spain would generate a high cost for the NHS, amounting to between €2 and €8.3 billion more than the current scenario without screening, depends on the characteristics of the screening. The non-acquisition of any CT scanner could reduce the net impact to between €1.9 and €7.5 billion.

Availability of databases and material for replication

This study does not rely on a specific database. All data inputs used in the budget impact model were obtained from available sources, including published literature and national statistics, which are duly cited throughout the manuscript. Therefore, all relevant materials needed to replicate the model are accessible through the referenced publications.

What is known about the topic?

Lung cancer is a malignant growth of cells in the lung or bronchial system and the first cause of death by cancer in Spain. Although a screening program could improve the prognosis of the disease, the budget impact of implementing of different screening scenarios in Spain has not been evaluated.

What does the study add to the literature?

A lung cancer screening program could generate an additional cost of between €2028.98 and €8301.35 million for the Spanish National Health System, compared to the scenario without screening.

What are the implications of the results?

The implementation of a lung cancer screening program could have a high budget impact on the Spanish National Health System, which should be taken into account during the decision-making process.

Transparency declaration

The corresponding author, on behalf of the other authors guarantee the accuracy, transparency and honesty of the data and information contained in the study, that no relevant information has been omitted and that all discrepancies between authors have been adequately resolved and described.

Authorship contributions

A. Hernández-Yumar participated in the design, acquisition, analysis, and interpretation of data, as well as drafting the work. C. Valcárcel-Nazco and L. García-Pérez participated in the design, acquisition, analysis, and interpretation of data, and critically reviewed the work. P. Cantero-Muñoz critically reviewed the work. L. García-Pérez and P. Cantero-Muñoz contributed to project administration. All authors read and approved the final manuscript.

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Conflicts of interest

None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gaceta.2025.102515.

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