Health Policy 114 (2014) 15–30

Contents lists available at ScienceDirect

Health Policy

journal homepage: www.elsevier.com/locate/healthpol

Atlas of Variations in Medical Practice in Spain: The Spanish National Health Service under scrutiny

Enrique Bernal-Delgado[a,*], Sandra García-Armesto[b], Salvador Peiró[c], On behalf of the Atlas VPM Group[1]

[a] Institute for Health Sciences in Aragón, IIS Aragón, c/San Juan Bosco 13, 50009 Zaragoza, Spain
[b] Institute for Health Sciences in Aragón, IIS Aragón, ARAI+D Foundation, Spain
[c] Centro Superior de Investigación en Salud Pública, Valencia, Spain

ARTICLE INFO

Article history:
Received 24 July 2012
Received in revised form 6 July 2013
Accepted 15 July 2013

ABSTRACT

Early in the 2000s, a countrywide health services research initiative was launched under the acronym of Atlas VPM: Atlas of Variations in Medical Practice in the Spanish National Health System. This initiative aimed at describing systematic and unwarranted variations in medical practice at geographic level-building upon the seminal experience of the Dartmouth Atlas of Health Care.

* Corresponding author.
E-mail address: ebernal.iacs@aragon.es (E. Bernal-Delgado).

[1] The Atlas VPM group is composed by: Andalucía: Díaz Martínez A (Hospital Virgen del Rocio de Sevilla); Goicoechea Salazar JA (Servicio Andaluz de Salud, Sevilla); Bermúdez Tamayo C (Escuela Andaluza de Salud Pública, Granada); Fornieles García Y (Escuela Andaluza de Salud Pública, Granada); Rivas Ruiz F (Hospital Costa del Sol de Marbella, Consejería de Salud); Jiménez Puente A (Hospital Costa del Sol de Marbella, Consejería de Salud); Rodríguez Del Águila MM (Hospital Virgen de las Nieves de Granada); Molina T (Agencia de Evaluación de Tecnologías Sanitarias de Andalucía); Aragón: Bernal Delgado E (Instituto Aragonés de Ciencias de la Salud-Instituto de Investigación Sanitaria Aragón); Abadía Taira MB (Instituto Aragonés de Ciencias de la Salud-Instituto de Investigación Sanitaria Aragón); García Armesto S (Instituto Aragonés de Ciencias de la Salud-Instituto de Investigación Sanitaria Aragón); Launa R (Instituto Aragonés de Ciencias de la Salud-Instituto de Investigación Sanitaria Aragón); Librero J (Instituto Aragonés de Ciencias de la Salud-Instituto de Investigación Sanitaria Aragón); Martínez Lizaga N (Instituto Aragonés de Ciencias de la Salud-Instituto de Investigación Sanitaria Aragón); Ridao M (Instituto Aragonés de Ciencias de la Salud-Instituto de Investigación Sanitaria Aragón); Seral Rodríguez M (Instituto Aragonés de Ciencias de la Salud-Instituto de Investigación Sanitaria Aragón); Abad Diez JM (Departamento de Salud, Gobierno de Aragón); Arribas Monzón F (Departamento de Salud, Gobierno de Aragón); Beltrán Peribáñez J (Departamento de Salud, Gobierno de Aragón); Pradas Arnal F (Departamento de Salud, Gobierno de Aragón). Asturias: Suarez Garía FM (Consejería de Sanidad. Principado de Asturias.). Canarias: Fiuza Pérez D (Servicio Canario de la Salud); Alonso Bilbao Jl (Servicio Canario de la Salud); Sánchez Janáriz H (Servicio Canario de la Salud); Domínguez Trujillo C (Universidad de Las Palmas de Gran Canaria). Cantabria: Romero G (Consejería de Sanidad). Cataluña: Tebe C (Agència d'Informació, Avaluació i Qualitat en Salut, AIAQS); Oliva G (Departament de Salut); Ortún Rubio V (Universitat Pompeu Fabra, Barcelona); Salas T (CatSalut- Servei Català de la Salut). Castilla León: Sacristán Salgado A (Dirección General de desarrollo sanitario); García Crespo J (Dirección General de desarrollo sanitario); Melgosa Arcos A (Dirección General de planificación, calidad, ordenación y formación); Sangrador Arenas L (Dirección General de planificación, calidad, ordenación y formación). Castilla la Mancha: García Sánchez MA (Consejería de Sanidad y AS de Castilla-La Mancha); López Reneo R (Servicio Salud Castilla-La Mancha, SESCAM); Solas O (Servicio Salud Castilla-La Mancha, SESCAM). Galicia: Atienza Merino G. (Conselleria de Sanidade de la Xunta de Galicia); Carballeira Roca C (Conselleria de Sanidade de la Xunta de Galicia); Castro Villares M (Servicio Galego de Saúde); Queiro T (Conselleria de Sanidade de la Xunta de Galicia). Extremadura: Montes S alas G (Escuela de Estudios de Ciencias de la Salud). Illes Balears: Castaño Riera EJ (Consejería de Salud, Familia y Bienestar Social); Zaforteza Dezcallar M (Servicio de Salud de las Illes Balears); Santos Terrón MJ (Consejería de Salud, Familia y Bienestar Social); Comendeiro Maaløe M (Consejería de Salud, Familia y Bienestar Social); Martín Martín MV (Hospital Son Llàtzer); Ferrer Riera J (Hospital Son Llàtzer).La Rioja: Cestafé A (Consejería de Salud). Madrid: Albarracín Serra A (Dirección General de Sistemas de Información Sanitaria, SERMAS); Bienzobas López C (Dirección General de Sistemas de Información Sanitaria, SERMAS). Murcia: Palomar Rodríguez J (Consejería de Sanidad de la Región de Murcia); Hernando Arizaleta L (Consejería de Sanidad de la Región de Murcia). Navarra: Álvarez Arruti N (Departamento de Salud de Navarra- Osasunbidea); Montes García Y (Departamento de Salud de Navarra-Osasunbidea); Rodrigo Rincón I (Departamento de Salud de Navarra-Osasunbidea). País Vasco: Aizpuru F (Grupo de investigación del País Vasco, Osakidetza-SVS); Errezola M (Departamento de Sanidad del Gobierno Vasco); Ibáñez Beroiz B (Centro de Investigación Biomédica-Navarra); Latorre García PM (Grupo de investigación del País Vasco, Osakidetza-SVS); Latorre A (Grupo de investigación del País Vasco, Osakidetza-SVS); Millán E (Osakidetza-SVS); Pérez De Arriba J (Grupo de investigación del País Vasco, Osakidetza-SVS). Valencia: Meneu R (Conselleria de Sanitat, Generalitat Valenciana); Peiró Moreno S (Centro Superior Investigación en Salud Pública); Calabuig J (Conselleria de Sanitat, Generalitat Valenciana); Sanfelix G (Centro Superior Investigación en Salud Pública); Sotoca R (Fundación IISS); Bauxauli C (Centro Superior Investigación en Salud Pública).

http://dx.doi.org/10.1016/j.healthpol.2013.07.013

Keywords:
Geographic variations in medical practice
Health system performance assessment
Spanish Atlas of Variations in Medical Practice, Spain

The paper aims at explaining the Spanish Atlas experience, built upon the pioneer Dartmouth inspiration. A few selected examples will be used along the following sections to illustrate the outlined conceptual framework, the different factors that may affect variation, and some methodological challenges.

1. Background

Early in the 2000s, a countrywide health services research initiative was launched under the acronym of Atlas VPM: Atlas of Variations in Medical Practice in the Spanish National Health System. The original idea was based on the genuine interest in exploring whether Wennberg's uncertainty hypothesis [1] and research findings [2] still held when observing an European National Health Service, the Spanish one (SNS). Basically, uncertainty hypothesis would state that:

a. Differences in disease patterns and other demand-side factors would not substantially explain variability in medical practice.
b. Variation would tend to be smaller when the degree of agreement on the value of a particular procedure is high; conversely, variation would tend to be larger when uncertainty about the relative value of a given procedure is the rule; and,
c. consequently, the more the uncertainty the more the room for physicians to subjectively weight the value of the procedure, based upon their heuristic learning and beliefs, enabling supply-side factors being influential in the decision-making process.

Beyond this academic interest, the political timing for the Atlas VPM's inception was especially interesting, concurrent with key changes in the SNS. The devolution of health competences to the regional governments (Autonomous Communities- AC) started off in the eighties with the fast-tracked ACs and went through a stepwise process to bring the others up to full autonomy until completion in 2002. As a result, the SNS was adopting a federal structure, built into 17 regional health systems holding total jurisdiction on regulation, funding, planning and provision of health services in their territory, accountable only to their respective parliaments [3]. This "natural experiment" warranted sustained analysis and comparison of variations across the country.

Likewise the Dartmouth Atlas, the aim of Atlas VPM has been on eliciting those systematic and unwarranted variations in population exposure/access to hospital services across the territory; systematic in terms of variations beyond chance and unwarranted in terms of variations unrelated to differences in population's health needs. These ten years of experience have produced many examples where testing and adapting the classic hypotheses underlying variations into the wider framework of performance analysis. At the same, the continuous contrast with Dartmouth's context has also yielded methodological alternatives dealing with different data and political context.

1.1. The Atlas VPM conceptual framework

In line with the widely accepted OECD health systems performance assessment rationale [4], Atlas VPM approaches population exposure to healthcare and its implications in terms of analysing equitable access to effective care, technological adoption, and efficiency in planning and delivery of care.

The conceptual framework adopted attaches to each indicator two informative attributes: its value and its variation across the territory. The value-attribute informs a judgement as to whether utilisation reaches an acceptable level using as a reference "standard" expectation. The variation-attribute signals whether the systematic differences observed across territories are unwarranted and, thus, need to be tackled. Population characteristics must be ruled out as sources of variation using the appropriate statistical treatment.

In addition, the meaning of the indicators and their attributes differ according to the service under study – for example, following the classical categories of care proposed in the Dartmouth experience, value and variation will have a different connotation in (a) effective care, where treatment has been proven effective in any patient; (b) preference-sensitive care, where a perfectly informed patient could ideally opt for a treatment among several "appropriate" options; and (c) supply-sensitive care, where uncertainty about the effectiveness of a treatment facilitates supply-side factors to drive medical decisions.

Atlas VPM revisited the aforementioned categories, given that the Spanish National Health Service quite differs from that one depicted in the Atlas of Dartmouth. For the Spanish context (a highly regulated system with universal mandatory coverage for a very comprehensive benefits basket, with general practitioners acting as gate-keepers, a limited capacity for patients to choose providers, and a different structure of incentives for payers, providers and patients), while the effective care category has been proven quite suitable, supply and especially preference-sensitive categories are more problematic; for example, variations in preference-sensitive care are not expected to benefit from patients' choice, since providers choice is limited and patients-doctors agency relationship is essentially biased towards the side of professional "preferences". Thus, rather than taking "prior" stakes as to the underpinning factors and solutions, the Atlas framework has chosen to re-define relevant care categories in reference to their proven effectiveness, leaving the door open for contextual analysis to reveal the drivers of utilisation and variation across the territory. Therefore, the categories adopted in Atlas VPM have been:

1. Effective care – proven effectiveness for any patient.
2. Effective care with uncertain marginal benefit (benefit-risk balance) in non-average patients – patients for whom there is insufficient evidence of effectiveness.
3. Lower-value care – no evidence about its effectiveness.

These categories are not normative- it would not be proper using them in such a way, given the ecologic nature of geographic variation studies. They merely provide a frame under which further dialogue on the underlying causes of variation might be fed.

Finally, the decision-making structure is built into several hierarchies, with three main levels of decision: autonomous community and the smaller policy meaningful geographical units- in Spain, the so called Healthcare Areas and Primary Care Areas used in planning and healthcare services provision. Such modelling provides an opportunity for eliciting how much each decision-making level contributes in explaining the differences detected. This way, the Atlas can help in choosing priority targets for any intervention aimed at reducing variations and increasing levels of equity, quality and efficiency.

The paper aims at explaining the Spanish Atlas experience, built upon the pioneer Dartmouth inspiration. A few selected examples will be used along the following sections in illustrating the outlined conceptual framework, the different factors that may affect variation, and some methodological challenges.

2. Methodology

2.1. Design

The case studies presented are based on observational, ecologic designs; some additional exploratory analyses have been performed to enhance the interpretation of the results.

2.2. Population and setting

The Atlas VPM database contains information on each of the publicly funded hospital admissions in the country -around 5 millions per consolidated year (it includes all items in the national hospital discharges dataset: demographics, diagnoses, procedures, type of admission, type of discharge, relevant date, etc.). Each admission is assigned to the patient's place of residence (each one of the 199 administrative healthcare areas across the 17 Autonomous Communities, for a total population of some 46 Million inhabitants). For the purpose of this exercise, admissions in 2008 and 2009 were pooled accounting for 2 millions admissions per year.

2.3. Procedures and conditions under study

For the illustrative purpose of this paper, the set of conditions and procedures has been chosen to fit into one of the three categories previously described:

- In the case of effective care, Acute Myocardial Infarction (AMI) admissions, surgery in breast cancer, hip fracture repair, colectomy in colorectal cancer.
- As for effective-care with uncertain marginal benefits for patients outside the eligible group: Percutaneous Coronary Intervention (PCI) in AMI, knee-replacement, carotid endarterectomy, and C-section.
- Among the procedures considered as lower-value care: spinal fusion, prostatectomy in prostate cancer, tonsillectomy in children 15 and younger, non-conservative surgery in breast cancer for women 50–69 years old.

In Appendix A, ICD 9th-based specifications of each procedure are detailed.

2.4. Analyses

2.4.1. Describing variation

Different statistical approaches are taken to analyse the two types of attributes – value and variation- defined for each of the indicators used in Atlas VPM; for this particular exercise:

2.4.1.1. Value-attribute. It is measured calculating and mapping out procedure utilisation rates and ratios for each of the 199 healthcare areas existing in the SNS.

Age and sex standardised utilisation rates are used as the basic measure of exposure to care for the population living in each area. Depending on the type of procedure analysed (effective, uncertain marginal benefit or lower value) high levels of exposure could be interpreted either as good or liable for improvement.

The Standardised utilisation ratio (observed/expected) is a good indicator of exposure above or below expectation. Usually, this conventional expectation is built as "average" utilisation; the expected number of cases is calculated by indirect standardisation, applying to the area's population structure the national age and sex- specific utilisation rates -cases contributed by all areas referred to the national population age and sex strata.

When the observed cases do not statistically differ from those expected, the standardised utilisation ratio (SUR) will set on 1 (utilisation in the area conforms to the expectation, "average"). Values over 1 can be interpreted as the excess (relative) risk of exposure to a procedure for the population living in the area. Exposure below expectation is denoted by ratios between 0 and 1.

2.4.1.2. Variation-attribute. A crude measure of the magnitude of variation is the ratio of variation or extremal quotient (EQ_{5-95}.) comparing utilisation rates in the areas in the 95th and 5th percentile of the distribution. Along the same lines, the interquartile ratio (IQ_{75-25} or rate in the 75th to rate in the 25th percentile) would represent the variation within the central part of the distribution of rates.

However, these measures cannot rule out chance as an alternative explanation for the differences detected. Thus, two other statistics are estimated: the classical Component of Systematic Variation (CSV) and the Empirical Bayes statistic (EB). Both are based on the relationship between observed and expected cases for each healthcare area although the EB offers more robust estimations for small populations and low utilisation rates [5]. Values different from zero are interpreted as systematic differences in access to care. In principle, values zero or close to zero might point to homogeneous utilisation across the territory (once excluded differences in burden of disease). High SCV or EB values suggest that a significant part of the observed variation cannot be deemed random or attributable to differences in epidemiology; therefore, there is variability in exposure to care depending on the area of residence. How much variation? The more the value of EB (SCV), the more the systematic variation; however, given that there is not a prescriptive value in assessing the variation, empirical calibrators can be used to establish the relative importance of the variation detected. So, the EB value in the procedure of interest is compared with the EB value in the procedure acting as a calibrator, which usually stands for the lowest variation. This methodology has been largely used taking as calibrator hip fracture repair. In our case, the reference would be colectomy in colorectal cancer [see Table 1a–c].

2.4.2. Analysing main underlying causes

Notwithstanding the ecological nature of Atlas VPM data and the informative flaws when using real-life information sources, it is possible to provide insight on some relevant factors likely to influence variation. Atlas VPM uses different methods to explore underlying factors. Contingent on the rationale (i.e. "causal model") of each indicator, and on the data availability some of them are systematically used, whereas other requires specific research. For the purposes of this article, and for the particular cases under study, a short explanation of these techniques is provided in the coming paragraphs.

2.4.2.1. Burden of disease. At population level, age, sex, and in some procedures, social deprivation (see later) are considered as proxies of burden of disease in the 199 healthcare areas of the Spanish SNS. However, when possible (essentially contingent on the existence and quality of data) other proxies are used with a view of accounting for the actual prevalence or incidence of a particular event of interest. For the purposes of this paper, hip fracture rates have been used in knee replacement variation, rates of ischaemic disease as the burden of disease for PCI, rate of dystocic deliveries in the case of C-section, and rate of breast cancer interventions as proxy of breast cancer. When appropriate, generalised regressions are modelled to determine whether both phenomena, burden of disease and procedures rate correlate.

2.4.2.2. Social deprivation. Concentration curves and concentration indices (with their respective 95% confidence intervals) are frequently drawn and estimated. Average household income for each one of the 199 healthcare areas is usually analysed as a proxy of social gradient. When utilisation is biased against less affluent areas (pro-rich difference in effective care), models are estimated in order to determine whether income in the areas is an independent factor.

2.4.2.3. Supply. Supply is usually studied in Atlas VPM in order to explain whether the existence of specific services or the number of resources per capita within an area affect variation. The existence of an ecological hypothesis is a prerequisite to carry out specific analyses, though. In the procedures in this paper, models are explored as follows: in the case of PCI using as a factor the existence of haemodynamic theatre, in the case of Endarterectomy the existence of an specialised facility, and in the case of non-conservative mastectomy the lack of radiotherapy services.

2.4.2.4. Concentration of population 30 min away from a specialised service. The concentration of population around specific services tends to explain both wealth and supply, when it comes to studying elective surgery. Although 80% of the Spanish population lives less than 30 min away (time-distance) from an acute-care hospital, some specific studies might benefit of particular analysis. In the case of this paper, all the procedures within the uncertain benefit-harm balance and lower-value categories are explored.

2.5. Information sources

All the analyses are carried out using the Atlas VPM Data-warehouse (VPM-DWH), a consolidated set of files including: (1) a hospital discharge dataset with the whole universe of discharges produced in public hospitals since 2002 onwards, (2) demographic information (age and sex distribution) for each of the 199 healthcare areas composing the Spanish SNS, (3) characteristics of hospital supply structure and capacity information for each of the public hospitals in the country both at hospital and geographic level, and (4) socio-economic data –average household income, rate of educational levels, rate of unemployment, etc. – disaggregated at healthcare area level.

3. Results and underlying factors

In order to ease the reading, this section describes the most typical findings referred to the three categories of procedures laid in the aforementioned taxonomy. At the same time, it provides insight on possible underlying factors, using when needed or appropriate some of the methods referred in the previous section.

The procedures in this work represent 190,540 episodes of effective-care, 287,038 of care with unclear marginal benefit for non- primary-eligible patients, and 50,848 episodes of lower-value care. The smaller variation is observed in colectomy in colorectal cancer (EB = 0.03), whereas the largest variation was observed in carotid endarterectomy, knee replacement and prostatectomy, varying as high as 22.6 times, 11.7 times and 10.6 times more than colectomy in colorectal cancer, respectively.

Table 1a–c shows the number of cases per procedure as well as the utilisation rates and the magnitude of the variation observed across areas (including the systematic fraction) Fig. 1a–c are representing graphically (dot plots) the observed variation. Table 2a–c (and maps 2a–c) depict the uneven population exposure to the different types of care. Fig. 3a–c represent the social gradient effect. All the tables and figures are split down into the three categories of care.

Table 1
Magnitude of variation in several conditions and procedures.

(a) Effective care

	Hip fracture repair	Colectomy	Mastectomy breast cancer	AMI
Cases	84,442	31,239	16,072	58,787
Crude rate	56.21	19.76	18.13	39.47
SD rate	56.95	19.67	18.20	39.49
Min rate	3.88	8.82	8.72	18.14
Max rate	89.97	30.50	36.70	80.68
P_5 rate	28.28	13.13	11.28	22.77
P_{25} rate	48.67	17.04	14.83	31.63
P_{50} rate	58.46	19.72	17.55	38.45
P_{75} rate	67.53	22.65	20.93	45.76
P_{95} rate	76.94	26.01	26.72	63.04
EQ5-95	1.89	1.76	2.00	2.03
IQ25-75	1.35	1.30	1.38	1.40
CSV	0.07	0.03	0.04	0.09
EB	0.08	0.03	0.04	0.08
EB Ratio*	2.6	1	1.3	2.6

(b) Effective-care with uncertain marginal benefit in non-average patients

	PCA	Knee replacement	Endarterectomy	C-section
Cases	42,993	69,106	3016	171,923
Crude rate	29.01	49.16	1.94	39.45
SD rate	28.84	49.40	1.74	40.76
Min rate	0.62	2.07	0.00	14.70
Max rate	84.00	110.46	6.71	94.14
P_5 rate	8.65	19.31	0.00	24.33
P_{25} rate	18.63	37.11	0.59	32.62
P_{50} rate	27.34	48.14	1.50	39.26
P_{75} rate	36.14	62.61	2.58	47.40
P_{95} rate	56.64	82.09	4.54	62.10
EQ5-95	6.39	2.98	–	2.07
IQ25-75	1.93	1.60	4.20	1.40
CSV	0.22	0.18	0.39	0.11
EB	0.35	0.21	0.68*	0.08
EB ratio*	7	11.7	22.6	2.6

(c) Lower -value care

	Spinal fusion	Prostatectomy	Tonsillectomy	Non-conservative Mastectomy
Cases	5600	8841	31,021	6441
Crude rate	3.43	12.37	23.03	6.63
SD rate	3.36	12.18	23.17	6.49
Min rate	0.00	0	3.12	0
Max rate	13.86	35.13	78.31	16.24
P_5 rate	0.72	2.66	8.06	1.97
P_{25} rate	2.13	6.95	14.89	4.64
P_{50} rate	2.90	11.42	20.64	6.25
P_{75} rate	4.32	15.42	29.19	8.14
P_{95} rate	7.30	28.12	45.86	11.87
EQ5-95	4.82	5.39	3.94	3.41
IQ25-75	1.91	2.04	1.80	1.66
CSV	0.24	0.23	0.24	0.12
EB	0.24	0.32	0.24	0.10
EB ratio*	8	10.6	8	3.3

* Ratio between the EB value in each procedure and the lowest EB value (colectomy).

3.1. *Effective-care*

The standardised utilisation rates for this type of care range from 56 hip fracture repairs per 10,000 inhabitants to 18 mastectomies per 10,000 inhabitants (Table 1a). EQ5-95 values suggest some degree of variation 1.89-fold in hip fracture repair, 1.76 in colectomy, 2.00 in breast cancer surgery and 2.03 in AMI. The very low systematic

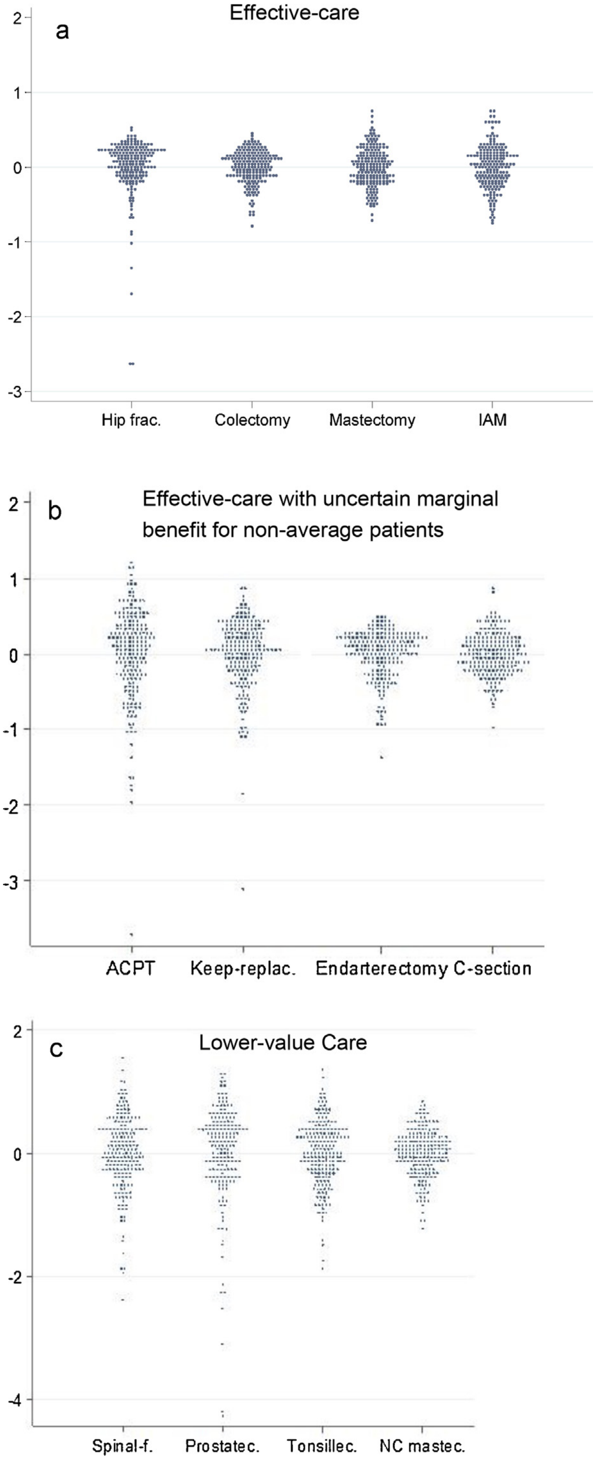

Fig. 1. Variation in several procedures. Legend: *y* axis is representing age-sex standardized log-rates of various procedures. Note: Each dot represents the standardized rate for each one of the 199 healthcare areas in Spain. Note that rates are represented in a log-scale centred in zero-value enabling comparison across procedures with different basal rates.

variation in the 4 procedures (less than 0.10 for both CSV and EB) is consistent with evidence.

Fig. 1a portrays the level of exposure of the population living in each area (dots represent the standardised rate of procedures log-transformed and centred on the mean to allow for comparison across very different volume of procedures). In accordance with IQ 25–75 figures, and compared with variation in the other categories (Fig. 1b and c), most of the areas are concentrated around the median–value. Population living in the areas in percentile 75th show 24% more hip fracture repairs, 28% more colectomies, 16% more breast cancer surgeries and 20% more myocardial infarctions (Table 2a).

As for the interpretation, since paths of care for the respective conditions are well established (uncontroversial indications) and in the absence of barriers to access in the SNS, these utilisation rates and variations are likely to represent an appropriate response of the healthcare system to the specific burden of disease in a definite population.

3.2. *Effective-care with uncertain marginal benefit for non-average patients*

For the procedures in this category of care, the average standardised utilisation rates range from 49 knee replacements per 10,000 inhabitants to 1.94 endarterectomies per 10,000 inhabitants (Table 1b). Extremal quotient amounted up to 2.98 in the case of knee replacement, up to 6.39 in the case of PCI and 2.07 in the case of C-section (in Endarterectomy EQ equals infinite because of the number of areas with no cases). The statistics of systematic variation shown in Table 1b indicate that a substantial part of the variation observed is systematic and therefore suggest relevant divergence in utilisation across areas – 30% of the variation is systematic in the case of PCI, 21% for knee replacement and 68% in Endarterectomy. C-section is the exception, showing only 8% unwarranted variation.

The standardised utilisation ratios are mapped out in Fig. 2b, showing the relative level of population exposure. Beyond this landscape overview (Table 2b summarises the actual figures per percentile), population living in areas where rates are above the 75th percentile) are getting 17% more PCI than expected (SUR 1.17), 40% more knee replacements (SUR 1.40), 36% more endarterectomies (SUR 1.36) and 29% more C-sections (SUR 1.29). Going to the extreme, 5% of the areas (the 10 areas in percentile 95) are getting 82% more PCI, 80% more knee replacements, 230% more endarterectomies and 68% more caesarean sections.

Knee replacement yields a clear benefit in those patients with a significant level of pain, stiffness, and disability. Conversely, benefit-risk balance is uncertain in patients with mild or poor levels of suffering. Using data from a Spanish cohort of patients with osteoarthritis, the indication for knee replacement was found inappropriate or uncertain in around 30% of patients. [6] With this prevalence of dubious indications, along with a 3-fold variation and a quarter of the areas with more than a 40% exposure over the expectation, it is reasonable hypothesising that in Spain, areas with high-rates of knee replacement will likely have a larger number of inappropriate cases; conversely, areas with low rates will likely have a larger number of appropriate ones.

Table 2
Population's exposure to health care in several conditions and procedures.

(a) Effective care

	Hip fracture repair	Colectomy	Mastectomy	AMI
Min SUR	0.08	0.43	0.50	0.49
Max SUR	1.65	1.42	1.91	2.18
P_5 SUR	0.52	0.64	0.60	0.60
P_{25} SUR	0.89	0.84	0.81	0.82
P_{50} SUR	1.06	0.98	0.97	1.01
P_{75} SUR	1.24	1.12	1.16	1.20
P_{95} SUR	1.42	1.28	1.49	1.63

(b) Effective-care with uncertain marginal benefit in non-average patients

	PCI	Knee replacement	Endarterectomy	C-section
Min SUR	0.03	0.05	0.00	0.40
Max SUR	2.68	2.47	3.44	2.58
P_5 SUR	0.29	0.45	0.00	0.67
P_{25} SUR	0.60	0.83	0.30	0.89
P_{50} SUR	0.88	1.07	0.78	1.06
P_{75} SUR	1.17	1.40	1.36	1.29
P_{95} SUR	1.82	1.80	2.30	1.68

(c) Lower value care

	Spinal fusion	Prostatectomy	Tonsillectomy	Non-conservative Breast surgery
Min SUR	0.00	0.00	0.13	0.00
Max SUR	3.82	2.90	3.38	2.33
P_5 SUR	0.20	0.00	0.35	0.46
P_{25} SUR	0.59	0.50	0.65	0.78
P_{50} SUR	0.80	0.85	0.90	1.01
P_{75} SUR	1.20	1.21	1.26	1.24
P_{95} SUR	1.99	1.90	1.96	1.81

However, confirming this will require patient-level data. Fortunately, pooling data from our dataset (geographic-based) with individual-data from an ad-hoc study exploring WOMAC scores – level of pain, stiffness and disability- in patients with an indication of knee replacement allows to confirm the hypothesis: areas with higher average WOMAC among intervened patients (those more appropriate cases) were areas with lower utilisation rates, while areas with lower average WOMAC values (those uncertain or inappropriate cases), had higher rates of intervention. [7]

Interpreting PCI variation would go in a different direction. The national rate stands for around 29 per 10,000 inhabitants. Nevertheless, areas in percentile 95th of the distribution are performing a number of procedures well beyond the national reference baseline, while those in percentile 5th barely reach a fourth of it. Seemingly, both underexposure (deficient access to PCI) and overexposure (areas intervening cases with unclear marginal benefit for the patient) might happen at the same time.

Differential epidemiology across areas (variation in the incidence of ischaemic heart disease) and differential access to specialised facilities (supply of or distance to haemodynamic units) were analysed in order to check over/under exposure hypothesis.

A model was estimated, regressing the standardised population rate of Ischaemic Hearth Disease admissions -proxy of burden of disease- in each of the 199 areas, together with the proportion of population living within 30 min-distance from a hospital with haemodynamic unit. The contribution of the burden of disease to explain PCI rates was found to be low. Only the areas in the 95th quintile (highest burden of disease) showed some correlation with a moderate to low r^2 value of 17%.

Apparently, the system is meeting the need in those areas with the highest rates. The issue lies on the reason behind the lack of association between burden and utilisation in areas with lower rates of ischaemic disease. The model provides some additional insight: living in an area with haemodynamic operating theatre would explain some 43% of the variation in PCI rates in areas with mild burden of disease, whereas barely explain the 13% of the variation in areas with the lowest rates of ischaemic disease. These figures may support the hypothesis of differential access to technology in those areas with mild rates of ischaemic disease, whereas in the areas with lower rates, the vast majority of the difference would be explained by the low burden of ischaemic disease.

Unexpected, the relatively small systematic variation in C-section (CSV 0.11, EB 0.08) requires further consideration. Notwithstanding the clear indications for C-section, this procedure is conventionally deemed to be highly sensitive to practice style, therefore higher levels of variation. Looking at the evolution since 2002 onwards, the rate of C-section is observed to increase, while variation is observed to decline, converging around higher rates [8].

Is this evolution reflecting an increasing need, or merely are women progressively more exposed to dubiously

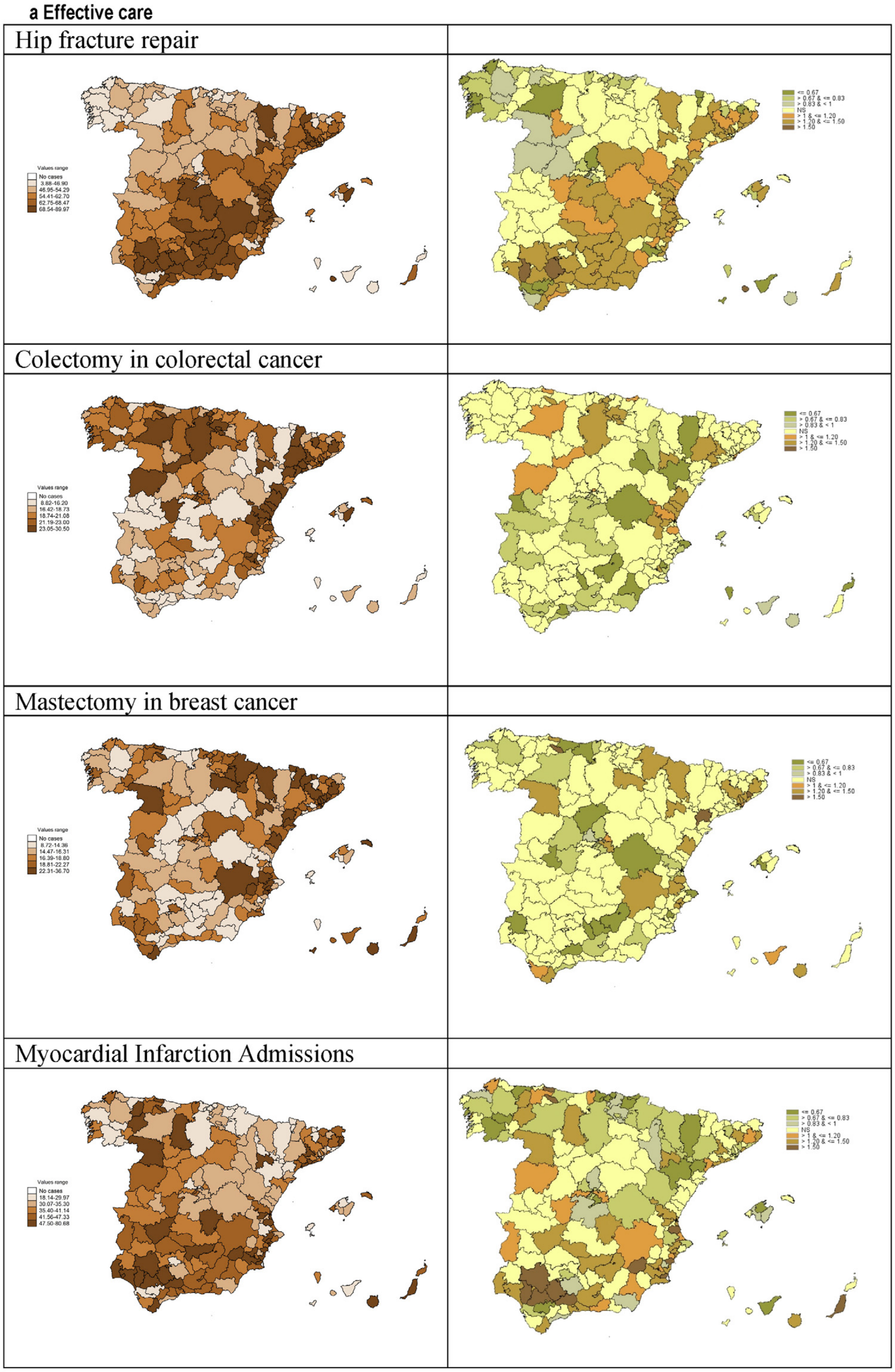

Fig. 2. Population relative exposure to different types of care across the 199 healthcare areas in the SNS. Legend: Rates are split down five colours representing the 5th quintiles in which the areas have been divided; the darker the colour, the higher the rate. Ratios are split down in seven areas. Yellow pale colour represents no statistical significance. Brownish colours represent more exposure than expected in three categories: 20% more exposure, 20 to 50% more exposure, more than 50% more exposure (the darker the colour, the more the exposure). Greenish colours represent less exposure than the expected, split down also in three categories: 20% less exposure, 20 to 50% less exposure, more than 50% less exposure (the darker the colour, the less the exposure). Note: Maps on the left represent age-sex standardized rates per 10,000 inhabitants. Maps on the right represent age-sex standardised utilisation ratios. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

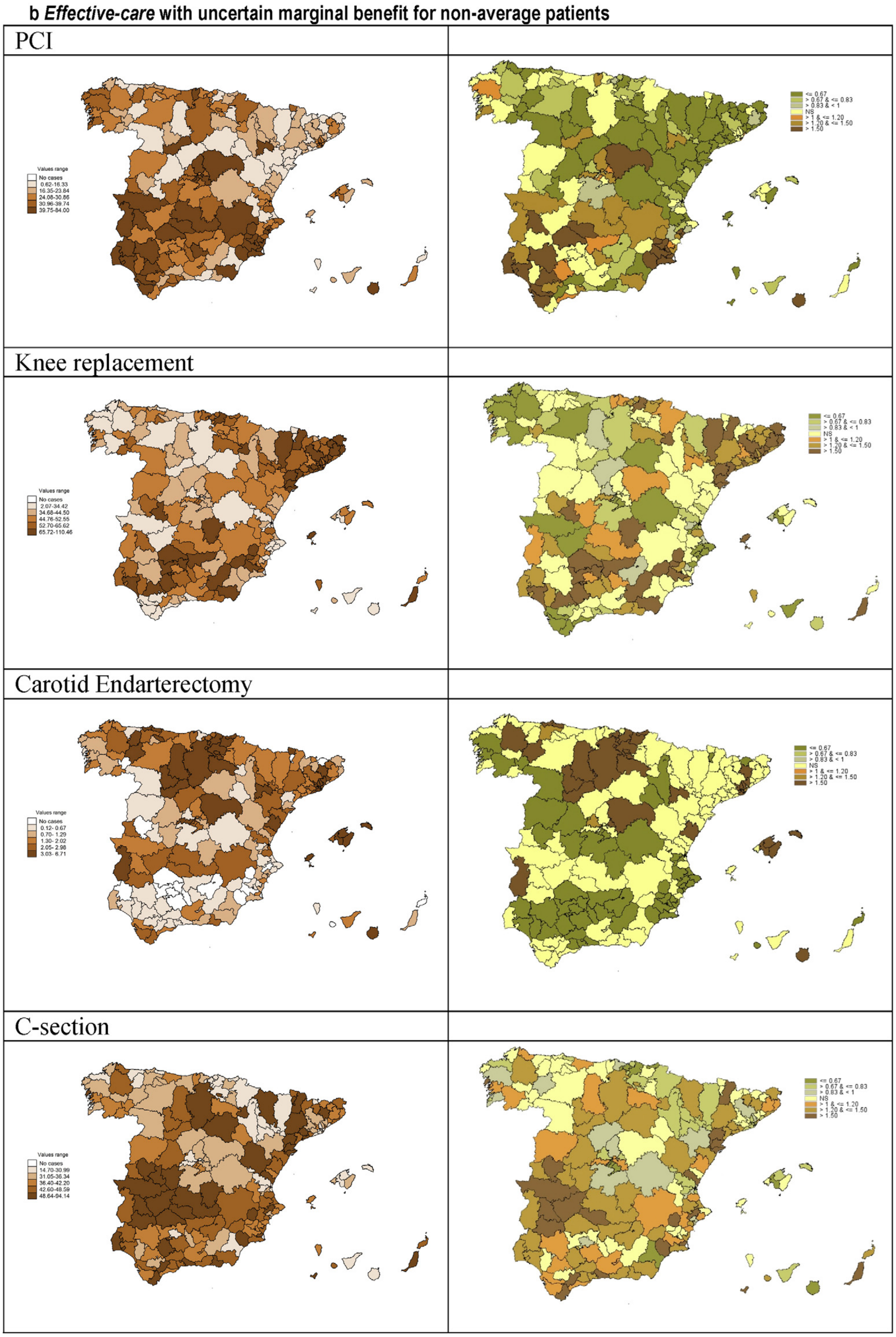

Fig. 2. (*Continued*)

needed C-sections? The joint analysis of C-section and dystocic delivery population rates (a measure of need) revealed that pathological deliveries barely explained a rough 11% of the observed variation in C-section rates. The hypothesis of homogeneous overexposure is more likely to be at the root.

Variation in Carotid Endarterectomy is unexpectedly the highest within the procedures studied in this paper.

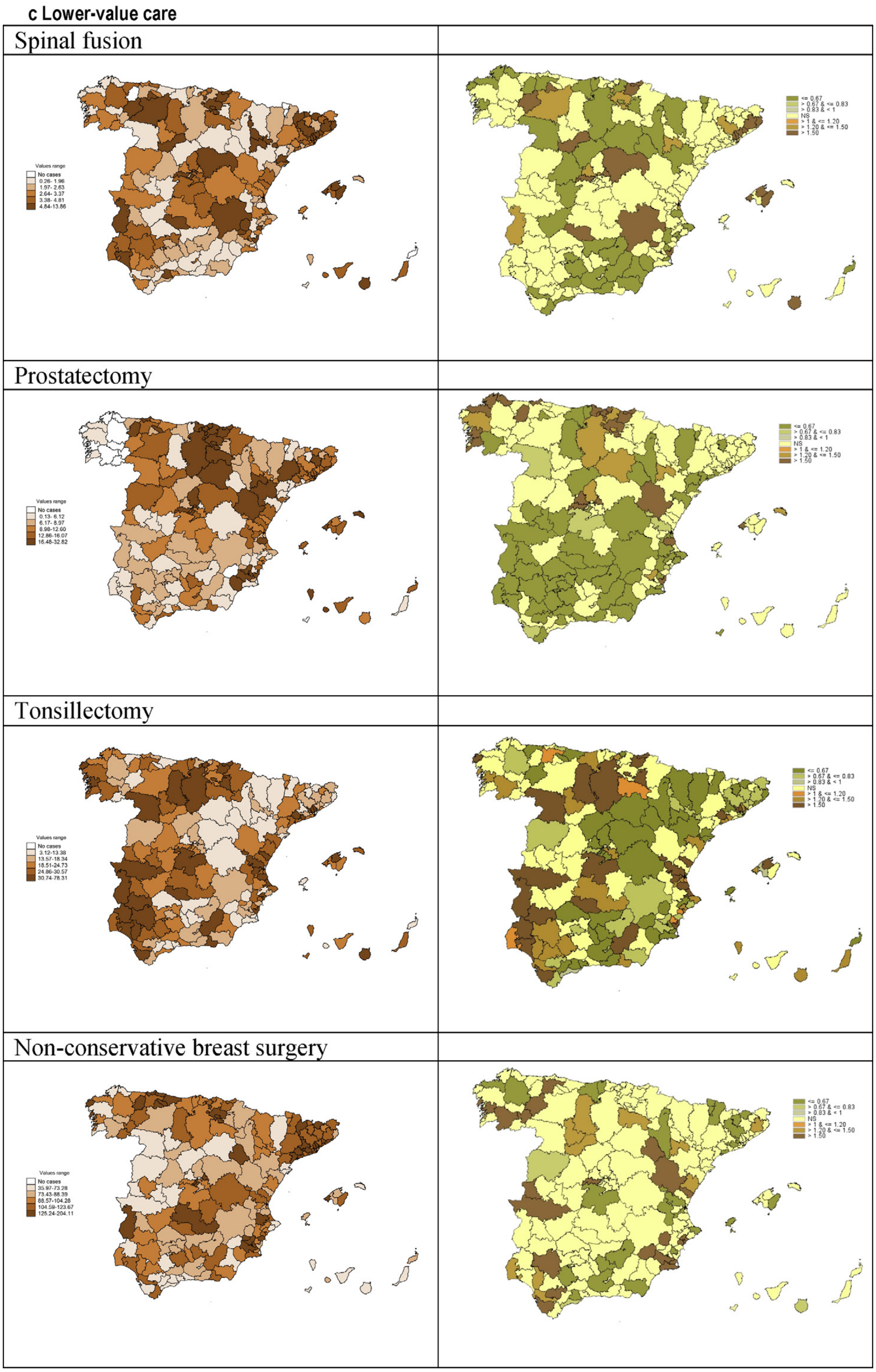

Fig. 2. (*Continued*)

Unexpectedly, given the fact that Endarterectomy is the standard procedure in symptomatic and asymptomatic carotid stenosis, and there are not remarkable differences in burden of disease across Spanish areas. Unlike PCI, the low rates of Endarterectomy (2 cases per 10,000 inhabitants) would not allow for any over/underexposure hypothesis.

More likely, variation could be attributed to two factors: (1) distance to the specialised surgical services; and, (2) different adoption of carotid stenting as an alternative

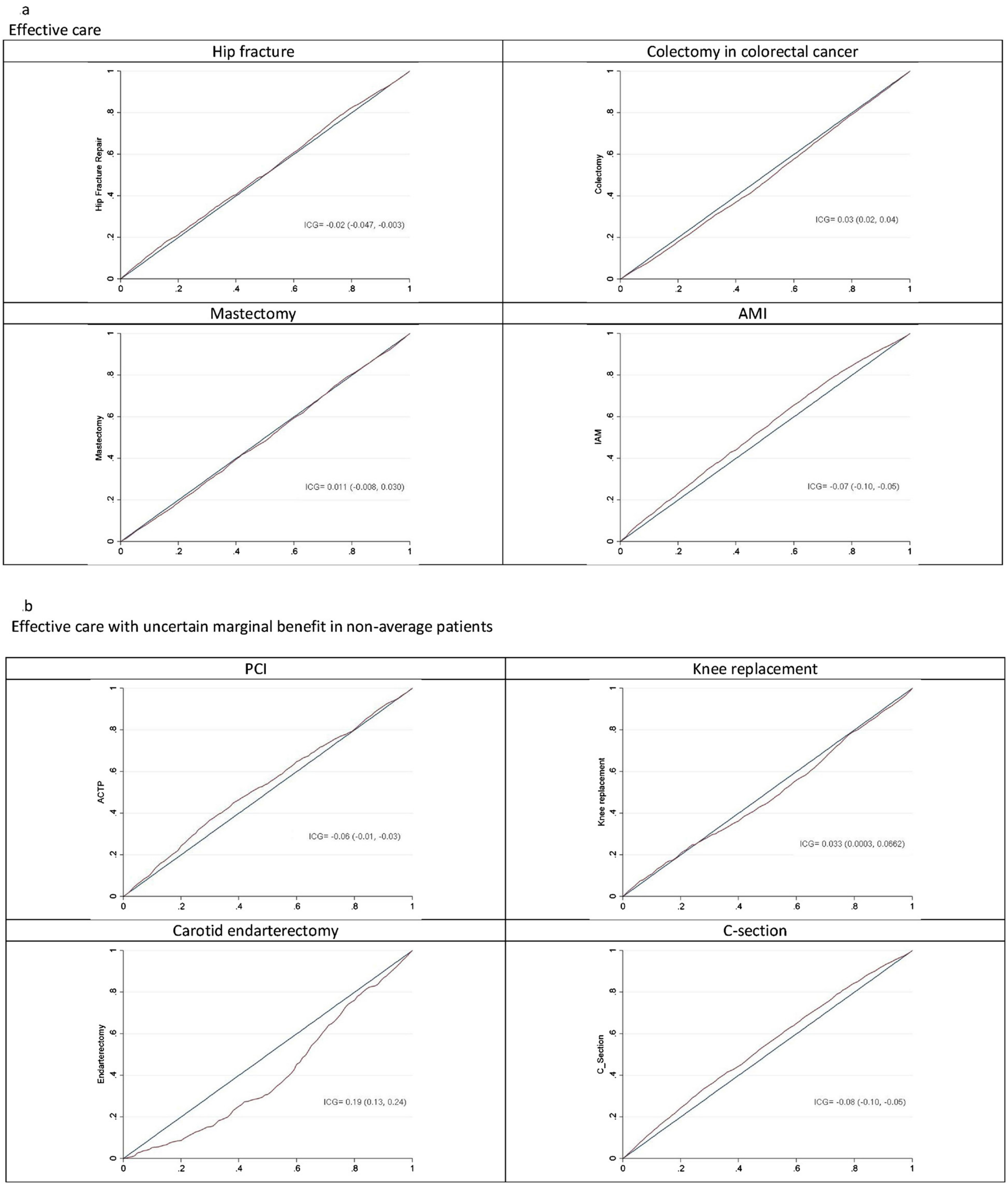

Fig. 3. Concentration curves and Gini coefficients. Legend: *x* axis represent the average household incomes within an area. *y* axis represents the age-sex standardized rates of procedures per 10,000 inhabitants. Both, are sorted from less to more income, and split down in quintiles of income. Note: the level of dominance of each concentration curve is determined by comparing to the diagonal line of 45°. If the concentration curve is below the diagonal (concentration index > 0), it is indication that rates are less concentrated in the first population group (lower economic level) and more concentrated in the last population groups (higher economic level). If the concentration curve is located above the diagonal (concentration index < 0) it indicates that rates are more concentrated in the first population groups (lower economic level) and less concentrated in the last population groups (higher economic level).

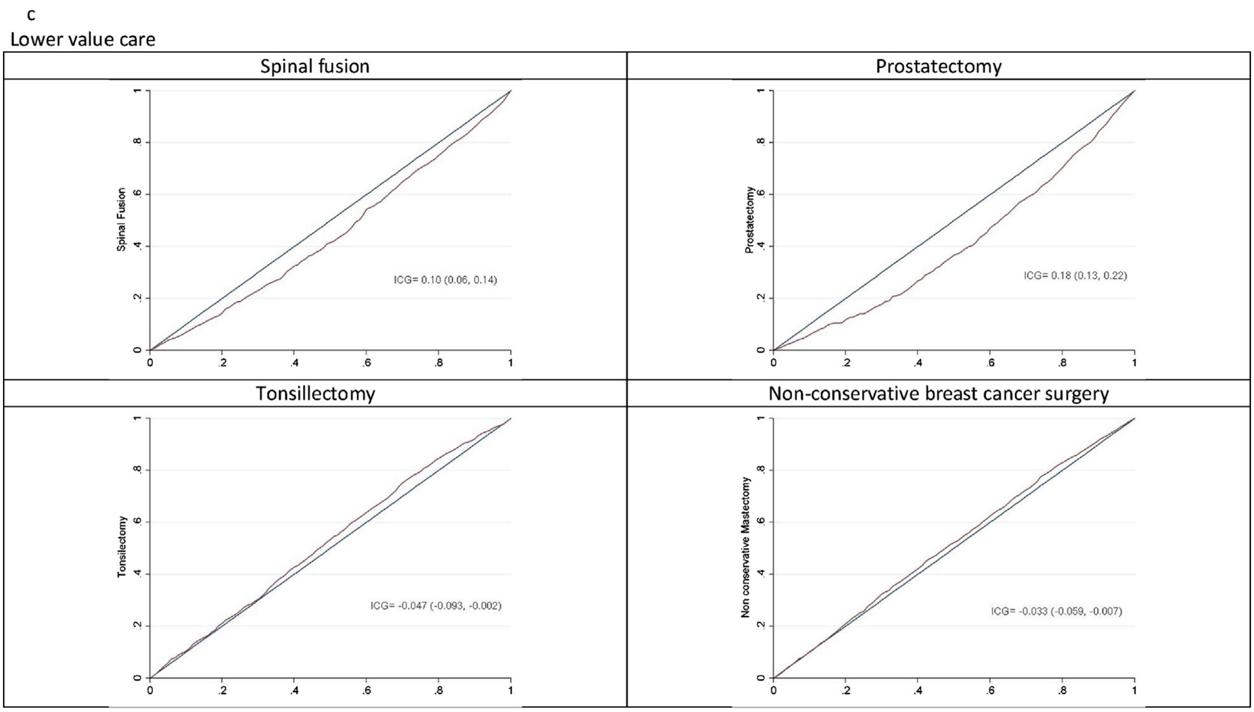

Fig. 3. (*Continued*)

to endarterectomy. In fact, urban areas (i.e. more affluent areas where referral hospitals and specialised services are established, Fig. 3b]) were found more exposed than rural areas; in turn, although the increasing use of stenting techniques in Spain they still are observed to be very locally concentrated (i.e. some places have already adopted the technique whereas others remain practicing endarterectomy) [9].

3.3. Lower-value care

Likewise in previous categories of care, Table 1c presents the corresponding number of cases and the distribution of utilisation rates across areas for the 4 examples of lower-value care included in this study. Figures range from 23 tonsillectomies per 10,000 inhabitant children to 3.43 spinal fusion interventions per 10,000 inhabitants 65 and older. The EQ5-95 are remarkably high: around 5-fold utilisation rates for spinal fusion and prostatectomy and 4-fold for tonsillectomy and 3.4 for non-conservative mastectomy in women aged 50–69 when comparing the 5% areas with the highest rates to the 5% with the lowest. In turn, EB values stand for moderate systematic variation in mastectomy (EB = 0.10) and high systematic variation in the remaining procedures: 24% above the expected by chance in spinal fusion and tonsillectomy, 32% in the case of prostatectomy.

Using the national average exposure as standard, populations living in areas whose rates are above the 75th percentile are getting 20% more spinal fusions (SUR 1.20), 21% more prostatectomy interventions, 26% more tonsillectomies and 24% more non-conservative mastectomies (Table 2c). In turn, 5% out of the 199 areas in Spain (areas above percentile 95) are exposed to 99% more spinal fusions than the standard, 90% more prostatectomy interventions, 96% more tonsillectomies and 81% more non-conservative mastectomies. The resulting maps are presented in Fig. 2c. Although figures tend to indicate high systematic variation in lower value procedures, non-conservative mastectomy shows relatively low variation in utilisation among women aged 50–70. However, comparing non-conservative mastectomy figures [10], with the variation expected on breast cancer burden proxy, total cancer breast cancer surgery (Table 1a and c), systematic variation in non-conservative mastectomy more than doubles the expected variation in burden of disease.

With regard to the interpretation of these four lower value procedures, in the Spanish SNS context, given the lack of financial barriers to those more cost-effective alternatives, and the scarcity of "do more" incentives (e.g. fee-for-service schemes are almost inexistent), variation in these techniques would seemingly depend on two factors: (1) different styles of practice and derived learning cascades (tonsillectomy, spinal fusion and prostatectomy); and (2) differential adoption of more cost-effective alternatives across areas (e.g. conservative and non-conservative breast cancer surgery). However, the populations' social gradient might have an influence in prostatectomy and spinal fusion (more affluent areas in Spain happen to have higher rates [11]) whereas deprivation might have an influence on non-conservative breast surgery and tonsillectomy (Fig. 3c). In fact, in the particular case of breast cancer surgery, an ad hoc study comparing both conservative vs non-conservative interventions, found income level to be an independent factor: whichever the age group, population in affluent areas were more likely to receive conservative mastectomy [concentration index of 0.12 (0.09–0.14)], whereas worse-off areas were more likely to receive non-conservative treatment [Concentration index −0.03 (−0.05 to −0.007)].

In any case, in interpreting variation in the procedures within this category –procedures dubiously effective or with a more cost-effective alternative, where risks might supersede benefits- both rate and variation matter; as for the first, the lesser the rate, the better; as for the second, variation should tend to be smaller, converging around lower rates.

4. Some methodological considerations

4.1. Need assessment

One of the key elements in studying geographic variation is skimming warranted from unwarranted variation. Typically, Atlas VPM uses age and sex structure in each area as a proxy to account for differences in epidemiology across healthcare areas (i.e. need for services at population level). Although generally a good surrogate of burden of disease, this strategy might not be enough to control for differences in need, particularly when healthcare area's population is not big enough to dilute differences by the "law of large numbers" (see later). Some articles have already pointed out this question [12].

The lack of routinely available epidemiological information at the geographical level of interest is a real challenge, even a hurdle, at least in Spain. Sources of information such as primary care administrative records, a good reference for the Spanish case since primary care practitioners act as gate-keepers, provide quite endogenous information -dependent on the coding or the diagnostic intensity rather than on the actual burden of disease [13]. Atlas VPM has implemented several alternatives to deal with this imperfect information [14]. For example, the use of Shared Component Modelling (SCM) [15,16], a set of tools developed within the Disease Mapping framework, offers some interesting properties. SCM allows the comparison of two or more concurrent phenomena, thus helping in modelling relevant questions in variation studies: men vs women access to care, technology substitution (modelled as the use of the superseded vs the emergent technology), disease rate vs procedure rate, the impact of two alternative organisational interventions, etc. SCM provides two patterns: a shared one in which latent underlying factors (burden of disease, for example) would affect similarly both phenomena across the territory; and a discrepant pattern, where latent factors would affect differentially either. The ability of this methodology to model unobserved or merely unmeasured factors is extremely useful in tackling "unknown" differences in need. The Atlas VPM group has recently published a good example of its properties; the analysis is focused on gender differences in rates of potentially avoidable hospitalisations in chronic diseases [17].

Besides demography, as observed in Fig. 3 and some of the aforementioned examples, Atlas VPM studies social gradient and deprivation – education level, unemployment, and income, generally. It is worth noting that social deprivation not necessarily relates to disadvantage. For example, better-off populations were more exposed to prostatectomy or spinal fusion –both, interventions considered as lower value care.

4.2. Attributing responsibility to different organisation levels

The Spanish case study has some advantages in terms of performance measurement. Unlike the Medicare population studied in the Dartmouth Atlas, the health map in Spain is precisely defined into health administrative circumscriptions whose boundaries and populations residing within them are quite stable over time. This organisation of services and populations reflects a hierarchical decision-making structure with three levels of responsibility within the SNS; from the smallest to the largest: primary care areas (first level of assistance, gatekeepers of the system), healthcare areas (level of operational management of hospital and primary care) and autonomous communities (full responsibility on planning and funding). The two latter (199 healthcare areas and 17 autonomous communities-ACs) are the usual units of analyses in the Spanish Atlas, whereas the primary care units are only used in specific analyses.

Attributing responsibilities to each one of these decision-making levels requires estimating which fraction of the observed variation is explained by each (primary care areas, healthcare areas and ACs). Atlas VPM generally focuses on the two latter, using several approaches: commonly, a graphical one (bubbles plots) and the estimation of variance partition coefficient (VPC). VPC [18] is a summary statistic representing the magnitude of variation attributed to the second level (autonomous community), beyond the variation explained by the first level (healthcare area). Fig. 4 shows two examples illustrating the use of these methods -mastectomy (a low variation procedure) and knee replacement (a high variation procedure). Bubbles represent healthcare areas and they are nested in the vertical axis within the corresponding AC, the larger the bubble the larger the population affected. In the case of mastectomy, variation across areas is larger than variation across ACs (ranging from 21.9 to 14.3 interventions per 10,000 inhabitants), suggesting a minor effect of the autonomous community. In the case of knee replacement, although variation across areas persists, variation across regions is more prominent -2-fold difference, from 68.7 to 34.7 interventions per 10,000 inhabitants. In terms of VPC, in non-conservative mastectomy, the variation attributable to the Autonomous Community is moderate to low – 12% (CI95% 5–26%) whereas in the case of knee replacement, the attribution to this level more than doubles those values −25% (CI95% 15–39%).

As for the interpretation, these figures point out towards influential ACs latent factors affecting variation beyond local decision (area-based) in knee replacement, along with a moderate effect in the non-conservative mastectomy, suggesting – in this case- a prior focus onto decisions taken at healthcare level.

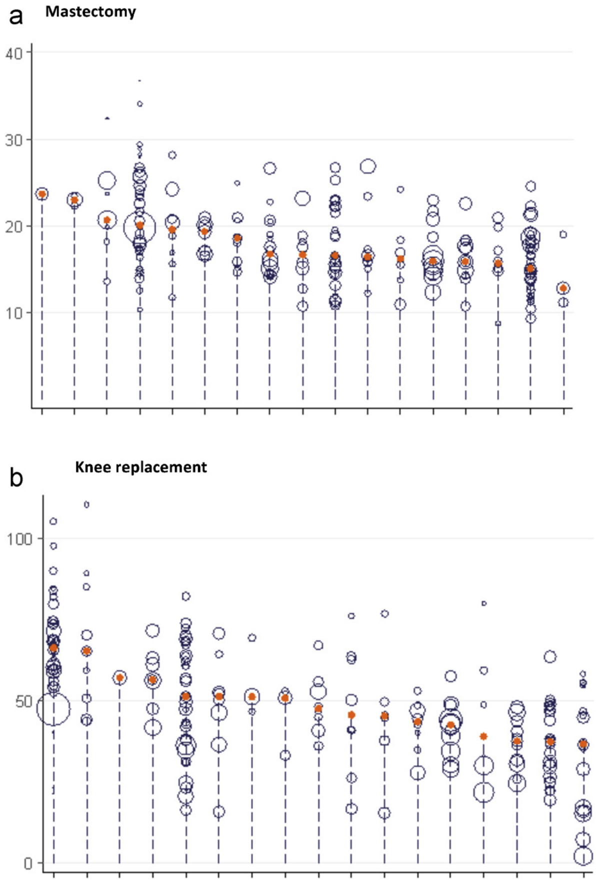

Fig. 4. Autonomous community vs healthcare area effects. Legend: *y* axis represent age-sex standardize rates of procedures per 10,000 inhabitants. Note: each column represents an Autonomous Community; bubbles represent healthcare areas within an Autonomous Community. The bigger the bubble, the greater the population.

4.3. *Some mathematical considerations in Atlas VPM*

Unlike the Atlas of Dartmouth, were Hospital Referral Regions are large and quite independent from each other, in the case the Spanish Atlas the effect of small numbers and interdependence across areas, have been acknowledged a threat to the validity of our observations.

The risk of small numbers has to do with the size of the geographical unit of analysis, and, consequently, heterogeneity might be confounded with true variation. Striking the balance between policy-relevance and big enough population's size can be delicate, especially in small or decentralised countries. In Spain a 10% of the areas has less than 50,000 inhabitants. The problem is logically more evident when digging into smaller units like primary care areas. As a matter of example, in the case of the Aragon Autonomous Community, for some 1.2 million inhabitants, there are 128 primary care areas. The 75% of these small areas has less than 2000 inhabitants.

Statistically speaking, small numbers pave the way for two phenomena: over-dispersion, especially when analysing relatively rare events, and deficit of discriminative power to elicit differences across units of analysis. Several alternatives are available to tackle these problems. The easiest way is aggregating several years' worth of data (available on yearly-basis); the drawback is that results might be less useful for decision-makers in need of information at least on annual basis. In the Spanish Atlas we have revisited Bayesian analytical techniques, to estimate the number of expected events, the statistics of variation, or the exposure of the population. As a matter of example, unlike what traditionally happens, in Atlas VPM, the standard estimator of Systematic Variation is not the Component of Systematic Variation, less robust with small numbers, but the Empirical Bayes statistic.

The other issue of interest is the assumption of independence across areas. Unlike what may happens in The Dartmouth Atlas, real life in Spain shows a strong interdependence across healthcare areas and neighbouring effects are much more often the case: they might share epidemiology (i.e. similar probability of exposure to healthcare); sometimes hospital services within an area are closely related to those in another (one acting as referring hospital other as referral); it is possible that surgeons assisting a population were trained in the hospital in the neighbouring area (i.e. learning cascades); or merely, populations move to seek care from an area to another (cross-border care). Whichever the reason, independence appears to be a fallacy when it comes to study variations in Spain. Some specific analytical approaches have been developed in the case of Atlas VPM either, Disease Mapping Techniques or Multilevel Multi-membership Analyses. [19–21] This way variation is decomposed into two fractions: variation attributed to "causes" within the area, and the variation attributed to the interdependence across areas. For example, in the case of PCI, a 19% (CI95% 14–24) of the variation might be attributed to events happening within the area, whereas a 13% (CI95% 5–24%) should be attributed to factors related to the interdependence with neighbours.

5. Implications for policy making

The wide systematic and unwarranted variation in the Spanish National Health Service and, the inferences and hypothesis drawn from them point to a first conclusion: System-wide efforts to measure and monitor variation across the territory are very valuable not only in the case of the USA and Dartmouth Atlases but also in the context of European National Health Services. As outlined for the Spanish case, the wealth of information produced allows for meaningful benchmarking tailored at policy-relevant levels of analysis, levering focused action to enhance the system performance. A sustained initiative able to monitor variations over time and investigate the factors underpinning them is a powerful tool in supporting evidence-based policy making and evaluating the impact of implemented measures.

Nevertheless there are several issues that should be taken into account to realise the full potential of this information:

1. The conceptual framework used in interpreting the results should fit the stakeholders' structure of incentives and organisational conditionings built into the institutional arrangements in each country. This way the results' relevance for action and local acceptability is improved.
2. Variations analysis is a monitor tool rather than a firm diagnosis; it helps in guiding further investigation: focusing scrutiny on those geographical units showing non-expected behaviour and on those technologies for which the phenomena is more dramatic or may entail more opportunity costs or inequity issues.
3. Sophisticating the modelling of clinical practice variation phenomena, introducing innovative probabilistic and multilevel methods and appropriate statistical treatment of some of the main hindrances is a need. The final goal of strengthening the analytical apparatus is to enhance the reliability of the results and thus improve the quality of the decisions that could be made on their basis:

a. The value of variation studies will depend on the specificity of the models analysing underlying factors. There is not a general causal model explaining variation; conversely, underlying factors may be different or affect variation across procedures and contexts differently.
b. Good models support suitable attribution of responsibility to different decision making levels: the decisions can be tracked-back and their specific impact on the observed variations carefully explored in conjunction with other factors.
c. From a performance measurement perspective eliciting interdependence across areas allows to flag the relative weight of within vs. neighbourhood factors in the production of unwarranted variations and, therefore to better focus healthcare policies and planning, as a more flexible reality.

Authors' contributions

EBD, SGA and SP are guarantors of the study, had full access to all the data, and take responsibility for the integrity and the accuracy of the analysis and results.

Conflicts of interest

None related to this article.

Funding

Since its inception, Atlas VPM benefits from public competitive funds (Institute for Health Carlos III grants# RTIC PI10/00494, PI08/90255, PI06/1673, PI05/2490, PI05/2487, PI04/2489, G03/202, C0309) and some private non-conditioning grants (IBERCAJA).

Appendix A. ICD 9th definitions.

Condition	Codes	Observations
Hip fracture repair	8200 to 8209 in DX1	Age: 65 and older Urgent admissions Excluded: 73314, E800 TO E84999
Colectomy in colorectal cancer	colectomy 4572–458, 4610–4614, 4620, 4622–4623,4841–4869	Age: 65 and older
	colorectal cancer 2303–2304, 1530–1539, 1540–1541, 1548* in DX1	Excluded: referred to other hospital
Mastectomy in breast cancer	mastectomy 8533–8536, 8541–8548, 8520–8523, 8525	Age: 65 and older Female
	breast cancer	Excluded: referred to other hospital
	2330, 1740 to 1749 in DX1	
Acute myocardial infarction	410* in Dx1	Age: 65 and older Urgent admissions Excluded: referred to other hospital
Percutaneous Coronary Angioplasty (PCI)	0066, 3601, 3602, 3605, 3606, 3607, 3609	Age: 65 and older
		Excluded: referred to other hospital
Knee replacement	8154–8155	Age: 65 and older Excluded: 73310, 73315, 8210–82139, 8220–8221, 8230–82399, E800 to E84999
Carotid endarterectomy	3812	Age: 65 and older
C-section	740, 741, 742, 744, 749, 7499	
Spinal fusion	810–8108	Age: 65 and older Excluded: 73310, 73313, E800 to E84999
Prostatectomy in prostate cancer	prostate cancer 185, 2334, 2365	Age: 65 and older Excluded: referred to other hospital
	prostatectomy 6021–6069	
Tonsillectomy	282–283	Age: less than 15
Non-conservative mastectomy	mastectomy	Age: women 50–69
	8533–8536, 8541–8548	Excluded: referred to other hospital
	breast cancer 2330, 1740 to 1749 in DX1	

References

[1] Wennberg JE, Barnes BA, Zubkoff M. Professional uncertainty and the problem of supplier-induced demand. Social Science and Medicine 1982;16:811–24.
[2] Wennberg J, Cooper M, editors. The Dartmouth Atlas of Health Care in the United States 1998. Chicago: American Hospital Publishing; 1998.
[3] García-Armesto S, Abadía-Taira MB, Durán A, Hernández-Quevedo C, Bernal-Delgado E. Spain: health system review. Health Systems in Transition 2010;12(4):1–295.
[4] Kelley E, Hurst J. Health care quality indicators project: conceptual framework paper. Paris: Organisation for Economic Co-operation and Development (OECD Health Working Papers No. 23); 2006.
[5] Ibáñez B, Librero J, Bernal-Delgado E, Peiró S, López-Valcarcel BG, Martínez N, et al. Is there much variation in variation? Revisiting statistics of small area variation in health services research. BMC Health Services Research 2009;9(April):60.
[6] Quintana JM, Escobar A, Arostegui I, Bilbao A, Azkarate J, Goenaga JI, et al. Health-related quality of life and appropriateness of knee and hip joint replacement. Annals of Internal Medicine 2006;166:220–6.
[7] Peiró S. Variaciones en la Práctica Médica y utilización inadecuada de tecnologías. In: López-Valcárcel BG, editor. en Difusión de Nuevas Tecnologías Sanitarias y Políticas Públicas. Barcelona: Masson; 2005.
[8] Villaverde Royo MV. Variaciones en la utilización de cesárea en los hospitales públicos del Sistema Nacional de Salud (tesis doctoral). Zaragoza: Universidad de Zaragoza; 2009.
[9] Tebé C, Abilleira S, Espallargues M, Salas T, Ridao M, Bernal-Delgado E, por el grupo Atlas VPM. Atlas de Variaciones en el tratamiento de la Enfermedad Cerebrovascular en España. Atlas Var Pract Med Sist Nac Salud 2013;5(1):380.
[10] Ridao-López M, García-Armesto S, Abadía-Taira B, Peiró-Moreno S, Bernal-Delgado E. Income level and regional policies, underlying factors associated with unwarranted variations in conservative breast cancer surgery in Spain. BMC Cancer 2011;19(11):145.
[11] Peiró S, Meneu R, Bernal-Delgado E. Variabilidad, desigualdad y efectividad en la utilización de servicios sanitarios. Revista Española de Salud Pública 2009;83:109–21.
[12] Peköz EA, Shwartz M, Iezzoni LI, Ash AS, Posner MA, Restuccia JD. Comparing the importance of disease rate versus practice style variations in explaining differences in small area hospitalization rates for two respiratory conditions. STATMed 2003;22(10 (May)):1775–86.
[13] Song Y, Skinner J, Bynum J, Sutherland J, Wennberg JE, Fisher ES. Regional variations in diagnostic practices. New England Journal of Medicine 2010;363(1 (July)):45–53.
[14] Congdon P. Health status and healthy life measures for population health need assessment: modeling variability and uncertainty. Health Place 2001;7(1):13–25.
[15] Knorr-Held L, Natário I, Fenton SE, Rue H, Becker N. Towards joint disease mapping. Statistical Methods in Medical Research 2005;14:61–82.
[16] Best N, Hansell AL. Geographical variations in risk: adjusting for unmeasured confounders through joint modelling of multiple diseases. Epidemiology 2009;20(3):400–10.
[17] Ibañez B, Librero J, Peiró S, Bernal-Delgado E. Shared component modelling as an alternative to assess geographical variations in medical practice: gender inequalities in hospital admissions for chronic diseases. BMC Methods in Medical Research 2011;11:172.
[18] Merlo J, Yang M, Chaix B, Lynch J, Råstam L. A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people. Journal of Epidemiology and Community Health 2005;59(9 (September)):729–36.
[19] Clayton D, Kaldor J. Empirical Bayes estimates of age-standardized relative risks for use in disease mapping. Biometrics 1987;43:671–81.
[20] Marshall RM. Mapping disease and mortality rates using Empirical Bayes estimators. Applied Statistics 1991;40:283–94.
[21] Browne WJ, Goldstein H, Rasbash J. Multiple membership multiple classification (MMMC) models. Statistical Modelling 2001;1:103–24.