Ana Johnson
and
Thérèse Stukel
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Medical Practice Variations in Elective Surgery

Enrique Bernal-Delgado[1], Manuel Ridao-López[1] and Sandra Garcia-Armesto[2]
(1)Unit for Research in Health Services and Policies, Institute for Health Sciences in Aragon (IACS), ISS-Aragon, Zaragoza, Spain
(2)ARAI+D Foundation, Institute for Health Sciences in Aragon (IACS), ISS-Aragon, Zaragoza, Spain

Enrique Bernal-Delgado (Corresponding author)
Email: ebernal.iacs@aragon.es

Manuel Ridao-López
Email: mridao.iacs@aragon.es

Sandra Garcia-Armesto
Email: sgarciaarm.iacs@aragon.es

Abstract

The study of variations in elective surgery may be considered a paradigm within the field of medical practice variations. It was the focus of the first seminal work on unwarranted variations where the initial insights and first major hypotheses regarding medical practice variations were based on patterns of variations seen in rates of elective procedures. The taxonomy regarding the underlying causes of variations was largely built upon elective surgery. The current debate on policy implications is populated with numerous examples of elective procedures.
Stemming from work by Glover, Wennberg, Gittelsohn, and McPherson and based on a comprehensive literature review, this chapter is aimed at characterizing variations in elective surgery. The chapter presents the current evidence on variations, describing and interpreting the factors affecting variations in the rates of elective procedures and highlighting lessons expected to have immediate implications for health policy.

Introduction

In the Beginning, There Was Tonsillectomy

The rise of the incidence of tonsillectomy is one of the major phenomena of modern surgery, for it has been estimated that 200,000 of these operations are performed annually in this country and that tonsillectomies form one-third of the number of operations performed under general anaesthesia in the

United States. There are, moreover, features in the age, geographical, and social distribution of the incidence, so unusual as to justify the decision of the Section of Epidemiology to devote an evening to its discussion. (Glover *1938*)

This is the text with which Sir Alison Glover started his dissertation in the Royal Academy of Medicine, *The Incidence of Tonsillectomy in School Children*, in which he described his concerns some 25 years after the School Medical Services first provided "grants in aid of treatment." It is worth highlighting some of the issues debated that evening.

- Before the inception of the School Medical Service (1907), there had been a general sense of a serious unmet need for tonsillectomies. However, in 1923 the first annual report on the service issued a clear warning against the "premature resort to operation." Notwithstanding the severe warning, the number of interventions steadily increased from 0.9 in 1923 to 2.2 per 100 children in 1931.
- Beyond the steady growth in the incidence, comparisons across areas "revealed striking contrasts in areas apparently somewhat similarly circumstanced," with the largest being an eightfold difference between Margate and Ramsgate, with the rates relatively constant over time in most of the areas.
- The social distribution was regarded as "puzzling," as was the geographical distribution of the incidence of the procedure. "Tonsillectomy is at least three times as common in the well-to-do classes. The more fortunate the child in all other circumstances, and the better the opportunities for careful nurture, so much the more is he liable to tonsillectomy," Glover stated in his conclusions.
- Since 1931, a gradual reduction in the incidence of tonsillectomy was observed in most areas. The reasons seemed to be the strong warning urging a conservative approach and several studies that were influential on medical opinion.
- However, Hornsey Borough experienced a dramatic reduction in the rates of interventions 2 years earlier than other regions, coinciding with the arrival of one Dr. Garrow. In his first year, the rate of operations on children decreased from 2.9 % to 0.2 %, remaining constant from then on. This decline was concurrent with a decrease in the rate of otitis media and other conditions for which tonsillectomy used to be performed.
- Finally, 85 deaths in children under 15 (yearly average) occurred from tonsillectomy, and "in all probability, this is a very conservative estimate."

Glover's reflections should be considered as the first exposition of variations in the rates of an elective surgical procedure, the associated factors, and the unintended consequences. His two groundbreaking conclusions, that dramatic geographic variations in tonsillectomy are unrelated to differences in need or epidemiology but rather amenable to a "prescription signature phenomenon" based on physician beliefs or unbounded enthusiasm and that damage due to care of doubtful value may overcome benefits, opened the door to rethinking the old paradigm of medicine as a science, with no possibility of unfounded variation.

... Not just tonsillectomy

Early in the 1970s, Wennberg and Gittelsohn (*1975*) compared rates of tonsillectomy, appendectomy, hemorrhoidectomy, hernia repair, prostatectomy, cholecystectomy, hysterectomy, dilation and curettage, and varicose vein stripping in 13 health service areas (HSAs) in Maine. They also added a comparison with some areas in Vermont. Some of the findings and reflections were the following:

- Age-adjusted incidence of surgical discharges within the largest HSAs (over 20,000 inhabitants) varied by 60 %, from 579 interventions per 10,000 inhabitants per year to 954 per 10,000 inhabitants. Smaller HSAs exhibited an approximately threefold difference.
- Some procedures varied more than others. Relative to Maine's average, the largest number of HSA outliers ($p < 0.01$) was found for tonsillectomy and hysterectomy. The smallest number of outliers was found for hernia repair and vein stripping.
- When comparing Maine and Vermont, a wide variation was found both within and between states: 37 % more tonsillectomies were performed in Maine than in Vermont, whereas 80 % more varicose procedures were done in Vermont. Maine performed 40 % more hysterectomies, and the range between the highest HSA in Maine and the lowest in Vermont was greater than threefold. Within HSAs, the variation in the utilization of the nine procedures was large and was independent of the total operation rates.
- Lastly, variation in the use of specific procedures had an impact on expenditures. Taking into account per capita expenditures on the nine procedures and the two extreme HSAs, total cost per capita varied 2.5 times, with tonsillectomy experiencing the most variation, over a fivefold difference.

These findings, together with previous evidence, led Wennberg and Gittelsohn to conclude that "small area geographic variations in use of surgical procedures are a rule for which there is yet no exception."

In arriving at their conclusions, Wennberg and Gittelsohn (*1975*), following the example of earlier researchers, ruled out alternative explanations such as differences in burden of disease, income, racial and social background, citizens' ability and wish to consume, insurance coverage, method of payment, organization models, and overall surgery intensity. They wrote, "we suggest this variety in use of specific technology reflects differences among physicians in their belief about effectiveness or in their judgment concerning how health-care needs are defined." Wennberg and Gittelsohn also reflected on the basis of these differences in professional opinion, concluding that in some instances, they involve differential diffusion of knowledge on the indications for a treatment or the value of a procedure. Finally, they also conclude that "it must be recognized that a fundamental reason for variation in incidence of surgery is uncertainty concerning the relationship between the use of a specific treatment and the status of the receiving individuals" (Wennberg and Gittelsohn *1975*).

... Not just in the USA

Significant differences between the US and the European health-care systems – particularly those developed as National Health Services – led researchers to investigate whether system features affected levels of variation. The seminal paper by McPherson et al. (*1982*) compared rates and variation in certain areas of New England, in the USA, counties in Norway, and districts in England. The paper focused on elective procedures (tonsillectomy, appendectomy, hysterectomy, cholecystectomy, prostatectomy, and hernia repair). The results showed that appendectomy rates varied slightly within and across countries, while tonsillectomy and hysterectomy rates varied the most (Fig. 1).

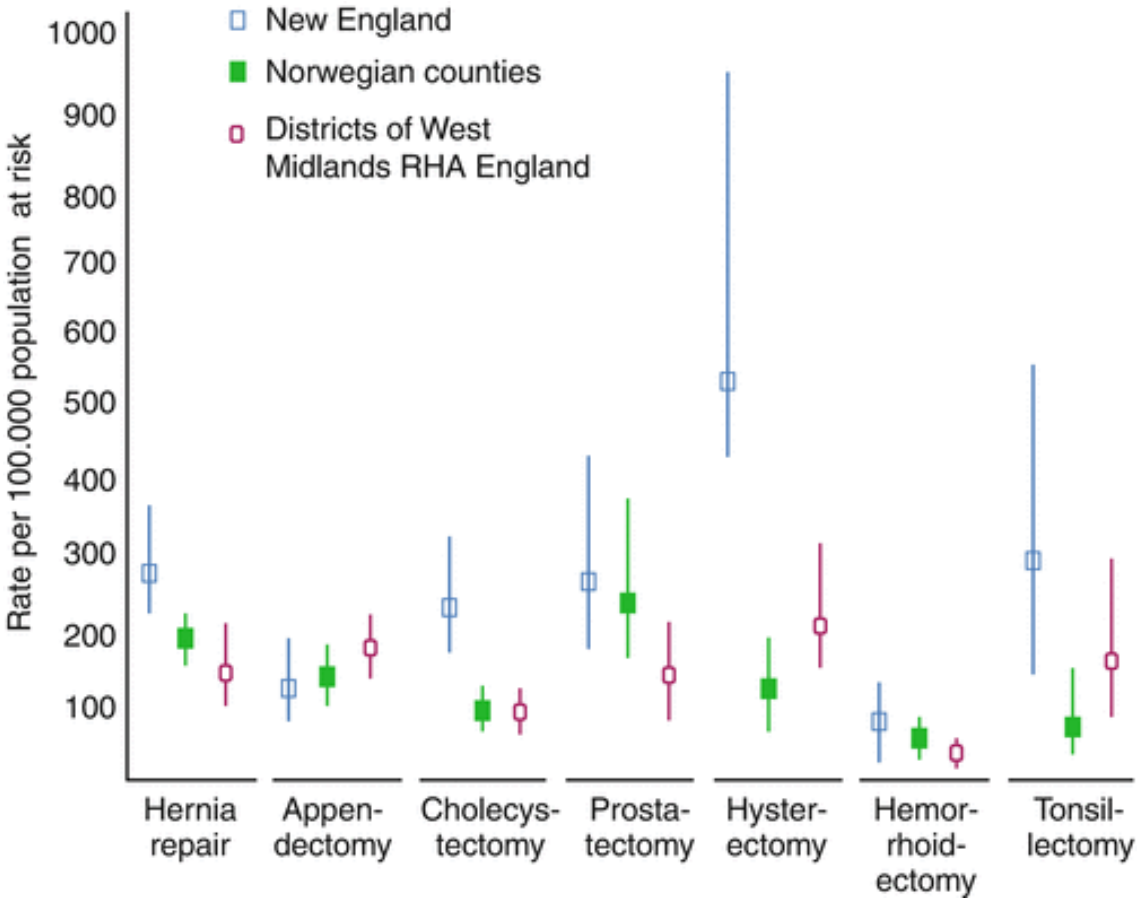

Fig. 1
International comparison of several elective surgical procedures (Note: Taken from McPherson et al. *1982*)

While highest utilization rates were found among New England's areas, the pattern of variation was consistent for all of the countries studied and was primarily related to the uncertainty regarding the procedures' indications rather than to institutional arrangements: "the specific pattern of variation exists across international boundaries and is independent of the national method of organizing or financing medical care."

As a result of this, Wennberg et al. (*1982*) coined the term *Uncertainty Hypothesis*, a concept that still inspires most of the research in variations in elective surgery. This hypothesis is summarized in the following four propositions (Wennberg *1990*):

(a)

Differences in disease patterns and other demand-side factors do not substantially explain variability in medical practice.

(b)

Variation would tend to be small when the degree of agreement on the value of a particular procedure is high.

(c)

Conversely, uncertainty about the relative value of a given procedure would drive physicians to subjectively weigh the value of the procedure, based upon their heuristic learning and beliefs.

(d)
Supply-side factors might be influential for procedures with high uncertainty about their relative value and will have a minimal effect in the case of strong agreement on the value of a service, procedure, or technology.

This chapter characterizes variations in elective surgery (Box 1) and the underlying "causes," highlighting the main findings and describing suggested remedies.

Box 1. Definition of Electric Surgery
Elective Surgery is defined as preplanned surgery as opposed to urgent or emergent surgery. Planned surgery is of critical interest in studies of medical practice variations since both physicians and patients are required to assess the need as well as the benefit-harm balance for intervention in specific circumstances.
Elective surgery is not always synonymous with need-driven interventions which makes the relationship between "decision time" and "decisions based on need" important when trying to understand the mechanisms underlying unwarranted variations.

Variations in Elective Surgery

Understanding Variations in Elective Surgery

Current Evidence on Variation in Elective Surgery

In support of the seminal research described above (Glover *1938*; Wennberg and Gittelsohn *1975*; Wennberg et al. *1982*; McPherson et al. *1982*; Wennberg *1990*), recent studies confirm unwarranted variation in elective surgery as the rule. Table 1 lists several ongoing initiatives that foster new research on unwarranted variations.**Table 1**
Some international websites of interest

Country/initiative	Institution	Description	Link
USA **The Dartmouth Atlas of Health Care**	The Dartmouth Institute for Health Policy and Clinical Practice. Geisel School of Medicine at Dartmouth	For more than 20 years, the Dartmouth Atlas Project has documented huge variations in how medical resources are distributed and used in the USA The project uses	http://www.dartmouthatlas.org

		Medicare data to provide comprehensive information and analysis about national, regional, and local markets, as well as individual hospitals and their affiliated physicians	
Ontario, Canada **ICES Atlases & Reports**	Institute for Clinical Evaluative Sciences (ICES)	ICES research atlases are comprehensive research studies that provide relevant information to providers, planners, and policy-makers on the effectiveness of the Ontario health-care system Covering a range of system-related and disease-specific topics, the atlases feature geographical breakdowns of regional patterns in health-care delivery. Findings, implications, and policy recommendations are provided to help guide quality improvement and decision-making in the dynamic climate of health care	http://www.ices.on.ca/Publications/Atlases-and-Reports
Spain **Spanish Atlas VPM**	Unit for Research in Health Services and Policies Institute for Health Sciences in	Atlas VPM is a nationwide research initiative aiming to describe unwarranted variation in population′s exposure to	http://www.atlasvpm.org

	Aragon, Spain	hospital care Since its inception in 2003, Atlas VPM provides insight to the 17 regions composing the Spanish National Health System about orthopedic surgery, cardiovascular care, pediatric care, mental health care, and lower-value care, as avoidable hospital admissions or adverse events	
New Zealand **Atlas of Healthcare Variation**	Health Quality & Safety Commission	The Atlas of Healthcare Variation displays easy-to-use maps, graphs, tables, and commentaries that highlight variations by geographic area in the provision and use of specific health services and health outcomes The Atlas is designed to prompt debate and raise questions about health service use and provision among clinicians, users, and providers of health services about why any differences exist and to stimulate improvement through this debate	http://www.hqsc.govt.nz/our-programmes/health-quality-evaluation/projects/atlas-of-healthcare-variation/
The Netherlands **Dutch National Atlas of Public Health**	Institute of Public Health and Environment Ministry of	Web-based atlas that maps the regional distribution of health-related matters. It targets	http://www.zorgatlas.nl/ http://www.nationaalkompas.nl/algemeen/menu-rechts/english/

	Health, Welfare and Sports	health professionals, such as policy advisers of the Dutch Ministry of Health, Welfare and Sports, regional and local authorities, and staff members of municipal health services The National Atlas works in cooperation with the Dutch National Compass of Public Health, the gateway to information about health and disease, risk factors, care and prevention	
UK **NHS Atlas of Variation in Healthcare**	Right Care National Health Service	The NHS Atlas of Variation series is intended to support local decision-making to increase the value that a population receives from the resources spent on their health care It supports the search for unexplained variations, the identification and attention to unwarranted variation, helping clinicians to understand what is going on in their area and where to focus attention to improve the care they provide	http://www.rightcare.nhs.uk/index.php/nhs-atlas/

There are several existing national initiatives whose goals are to monitor their respective health systems. However, comparisons across countries, using the analysis of unwarranted variations in international assessment of health system performance, are relatively recent. To our knowledge, there are only two initiatives currently pursuing this aim: one led by the Organisation for Economic Co-

operation and Development (OECD) and the other sponsored by the European Commission Seventh Framework Programme (EC FP7).

In 2012, "The OECD *Project on Medical Practice Variations*" started to collect data from 14 countries, including, among other indicators, rates of a number of four types of surgical procedures: C-sections, revascularization procedures (coronary artery bypass graft (CABG) and coronary angioplasty (PTCA)), and knee replacement (http://www.oecd.org/els/health-systems/medicalpracticevariations.htm). Preliminary work (McPherson et al. *2013*) used international data routinely collected at the country level to compare rates of five surgical procedures (i.e., cesarean section, hysterectomy, prostatectomy, hip replacement, and appendectomy) across OECD countries. It examined trends over time and compared age- and sex-specific rates using the most recently available data, for the subset of countries for which data were available. The report "shows substantial international variations for most procedures, but also striking similarities between countries; some procedures showed universal trends with trends in rates by sex and age behaving in very similar ways."

The European Collaboration for Healthcare Optimization (ECHO: www.echo-health.eu) is a pilot project that started gathering hospital databases from six European health-care systems (Spain, Portugal, Slovenia, England, Denmark, and Austria) in 2010. ECHO aims to explore equity in access, quality, and efficiency of health care at the hospital, health-care area, and regional and country level, focusing on identifying unwarranted variations using a set of well-established indicators adopted by international organizations such as the Agency for Healthcare Research and Quality (AHRQ), OECD, and EC. The initial focus is on cardiovascular and orthopedic procedures as well as potentially avoidable hospitalizations for chronic conditions and low-value procedures. Preliminary results have been widely presented to relevant audiences and available at http://www.echo-health.eu/?site=documents. Some of the intermediate results already point out interesting insights from cross-country comparisons regarding elective surgery. Figure 2 presents variation in colectomy in colorectal cancer, percutaneous coronary interventions, knee replacement, and prostatectomy in prostate cancer in populations aged 65 years and older in England, Portugal, Denmark, and Spain, along with the US Medicare rates obtained from the Dartmouth Atlas of Health Care (http://www.dartmouthatlas.org/).

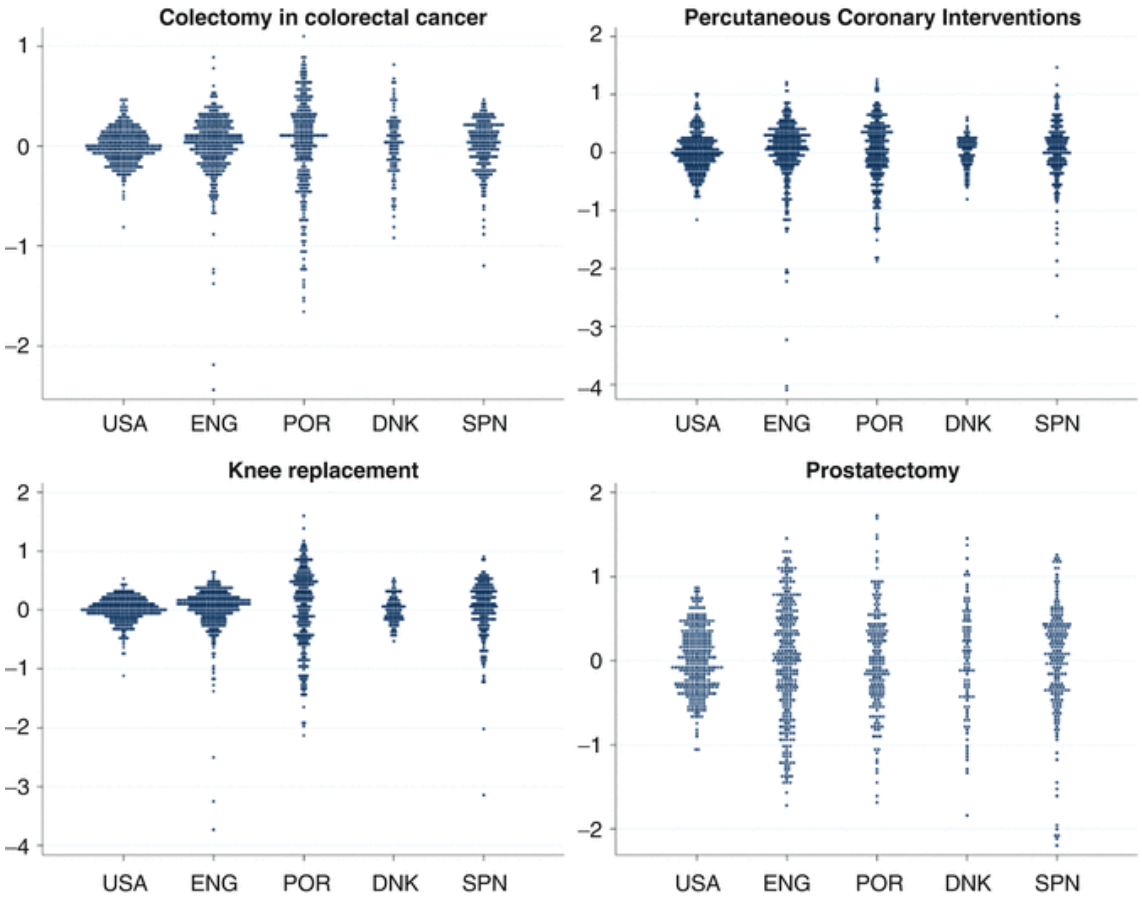

Fig. 2
International comparisons in ECHO countries and the USA

At first glance, Fig. 2 and Table 2 support results noted earlier in this chapter: in general, the highest procedure rates are observed in the USA, but the rates of colectomy for colorectal cancer, a fairly uncontroversial indication, are similar for all countries; this combination suggests a country/system effect. A second look seems to corroborate the *Uncertainty Hypothesis*. As expected, the least variation within and across countries is observed in colectomy for colorectal cancer (second proposition of the *Uncertainty Hypothesis*). At the other extreme, the largest within and cross-country variation corresponds to prostatectomy in prostate cancer, a procedure for which there is no clear agreement on appropriateness (third proposition of the *Uncertainty Hypothesis*).**Table 2**
International comparison across ECHO countries and the US rates and variations in four selected procedures

	USA	England	Portugal	Denmark	Spain
Colectomy in colorectal cancer					
Rate	15.2	16.02	19.3	17.9	19.6
RV5-95	1.7	2.3	5.3	2.8	2.1

EB		0.04	0.05	0.01	0.07
PCI					
Rate	102.6	35.9	28.2	59.4	33.6
RV5-95	2.9	5.1	8.4	2.3	5.1
EB		0.23	0.18	0.23	0.31
Knee replacement					
Rate	89.9	57.9	27.3	70.6	48.8
RV5-95	1.9	2.5	8.7	2.1	4.1
EB		0.11	0.69	0.15	0.19
Prostatectomy					
Rate	16.8	2.3	3.5	10.4	5.4
RV5-95	3.4	9.9	8	7.7	6.8
EB		0.6	0.1	0.23	0.33

Note: Data in this table match Fig. 2. Rate refers to age-sex-standardized rate; RV 5-95 is ratio of the 90th to the 5th percentile of rates. The EB EB (empirical Bayes) statistic estimates the systematic component of variation, i.e., variation not deemed random; the higher the EB value, the more systematic variation exists

A further look supports the theme presented in McPherson's cross-country study (McPherson et al. *1982*), i.e., there are no country-specific patterns across procedures with regard to variation (check, in Fig. 2, the values of the empirical Bayes (EB) statistic per procedure – a measure of the variation not deemed random – the higher the value, the lesser the probability of random noise).

Factors Influencing Elective Surgery Rates and Variation

Norman Rockwell's painting *Before the Shot* shows a child waiting for the doctor's intervention. The painting illustrates the long way the health-care system has come. Health-care systems are complex organizations with patients and professionals at the epicenter of decisions. According to the *Uncertainty Hypothesis* (Wennberg et al., 1990), medical decisions will depend, first, upon the degree of uncertainty regarding the indications for the specific procedure; but also, they will be contingent on

the interactions of many factors and their influence on the agency relationship between professionals and patients. Once random variation or information issues are ruled out (variation analyses must always check and account for these potential sources of noise and bias), the factors affecting variation in procedures' utilization rates can be classified as demand-side, supply-side, system, and outer system factors (Box 2).

Box 2. Selected Factors Affecting Medical Practice Variations

- **Demand-side**
  - Age
  - Sex
  - Burden of disease
  - Disability
  - Race
  - Expectations
  - Preferences
  - Willingness to use health care
- **Supply-side**
  - Physician
    - Knowledge
    - Training
    - Peer-pressure
    - Contractual relationships
    - Payment mechanisms
  - **Provider**
    - Organizational culture
    - Innovation adoption
  - **Organizational mechanisms**
    - Funding schemes
    - Network territorial distribution
- **System**
  - Mechanisms to mediate the interaction between supply and demand (implicit/explicit incentive structures)
  - Coverage breadth (population covered), scope (benefits basket), and depth (extent of financial coverage: cost-sharing and patient fees)
  - Availability of alternative services (long-term care, home care, etc.)
  - Budgetary mechanisms to control public expenditure in health care
- **Overarching system**
  - Socioeconomic gradients
  - Geographic barriers and accessibility
  - Budgetary mechanisms to control public expenditure

Note: Beyond these factors, analyses must check and account for random variation and data quality issues since they may bias the interpretation of the observed variations as unwarranted and systematic. Random variation might be due to small and/or heterogeneous size of the areas under comparison, infrequent events (procedures prone to sporadic use/rare outcome), or spurious time or spatial phenomena related to the event or affecting information systems. Data quality issues may affect utilization rates through insufficient availability of data on the numerator or denominator or through

differential data availability, such as differential under- or overreporting, coding errors, and coding practices across areas.

In order to illustrate the role of these underlying "causes" of variation, a number of elective procedures were chosen, and the literature published from 2003 onwards (PUBMED indexed) was reviewed. The search strategy (referred in Appendix 1) was not meant to be a systematic review but rather was chosen to provide readers with evidence about the relevance of supply, demand, and system, and outer system factors have shown more relevance and how they affect some of the most frequent elective surgeries. The list comprises tonsillectomy, cesarean section, hysterectomy, prostatectomy in prostate cancer, knee and hip replacement, and cardiac revascularization surgery. The following paragraphs summarize this evidence.

Tonsillectomy

Although extensively studied and highly controversial (due to uncertainty about its clinical value), overall tonsillectomy incidence increased in the USA from 126 per 100,000 children-years in the 1970s to 153 per 100,000 children-years in the period between 2000 and 2005, and adenotonsillectomy rates increased twofold. This increase in surgical rates was accompanied by a dramatic change in the indication for surgery: notably, the indication of upper airway obstruction rose from 12 % in 1970 to 77 % in 2005 (Erickson et al. *2009*). In Italy, although the overall incidence of tonsillectomy and adenoidectomy decreased slightly after the issuing of recommendations in 2003, adenotonsillectomy still increased by 18 %. Variation across the Veneto Region was dramatic, with a more than threefold factor across areas (Fedeli et al. *2009*). Also in Italy, a previous study found six-times variation across regions (Materia et al. *2004*).

Typically, supply-side factors have been argued to be the main lever for variation in tonsillectomy, particularly those factors linked to the physician (see Box 2). While there is a clear indication for the intervention in those cases presenting with three to four episodes of tonsillitis per year, the decision in cases of upper airway obstruction rests mainly on the interpretation of a patient's self-report of their medical history and documented clinical findings (van den Akker et al. *2003*; Jacobs et al. *2010*). This may explain the relevance of doctor-signature phenomena when studying tonsillectomy.

Several recent studies underpin the evidence of "physician-related factors." For example, in the Netherlands, professionals' (general practitioners or ear, nose, and throat (ENT) specialists) beliefs on the relative benefit of the intervention did not change after the publication of a randomized controlled trial (RCT) comparing adenotonsillectomy with watchful waiting in children with mild to moderate symptoms (van Staaij et al. *2004*) which found no difference in outcomes. Apparently, physicians were not aware of this conclusive piece of evidence or chose to ignore it. In another RCT, physicians in north England and Scotland seemed to favor tonsillectomy over medical treatment when the patient displayed negative outcomes or persistent episodes of sore throat, particularly in boys (Lock et al. *2010*). As a final example, a survey of Belgium physicians found that "surgical decision-making appears to be influenced by the number of years of ENT practice" (Jacobs et al. *2010*).

Cesarean Section

C-section is an effective intervention with clear indications. However, variation across regions is large: as large as two- to fourfold differences in the USA (Clark et al. *2007*), rates ranging from 16.1 to 27.5 per 100 deliveries in Canada (Baicker et al. *2006*; Hanley et al. *2010*), and dramatically increasing rates in France (Carayol et al. *2007*). Typically, demand-side factors, such as social

gradient or ethnicity, have been shown to explain some of the variation in the utilization of this procedure (Box 2). For instance, deprived areas in the UK (Fairley et al. *2011*), and areas with low levels of education in Spain (Márquez-Calderón et al. *2011*), showed low rates of utilization. Along the same lines, higher urban density areas in Taiwan were associated with higher odds of intervention, (Chen et al. *2008*) and White women in Brazil experienced the higher rates than any other ethnic group (Freitas et al. *2009*).

Several supply-side factors (see Box 2) have also been shown to play a role. The adoption of innovations enhancing the monitoring of the fetus such as two-dimensional ultrasound and cardiotocography reduced the variation in rates in Norway (Grytten et al. *2012*). In Spain, going into labor during a weekend was associated with a lower risk of C-section (Márquez-Calderón et al. *2011*). Provider density in the USA had a clear impact in the number of performed surgeries (Baicker et al. *2006*); in France seeking care in the private sector (Carayol et al. *2007*) was found to be an independent factor predicting the use of C-section in delivery, after adjusting for differences in delivery, mother, and newborn characteristics.

Hysterectomy

Hysterectomy in uterus cancer has been proven to be an effective and safe strategy to reduce mortality. Its variation is therefore quite small and essentially related to differences in cancer incidence (Peiró et al. *2009*). So interest in the study of variation in hysterectomy generally focuses on the use of hysterectomy in benign gynecological conditions, for example, genital prolapse or bleeding disorders; variations in the modality of the intervention (abdominal, laparoscopic, or vaginal access) are also of interest. With regard to the decision to intervene based on a benign condition, a more than twofold variation was found across providers in the Netherlands (Hanstede et al. *2012*). And although vaginal hysterectomy has been found to be superior (Ribeiro et al. *2003*; Bottle and Aylin *2005*), in the UK rates of abdominal access ranged from 25 % to 90 % across hospitals and from 75 % to 89 % across regions (Bottle and Aylin *2005*), while rates of vaginal access ranged from 2 % to 86 % in Denmark (Nielsen et al. *2011*) and from 43 % to 64 % in the Netherlands (Hanstede et al. *2012*). Demand-side factors seem to be at play in explaining such variations: age (i.e., older women) has been found to be associated with accessing the uterus through the vagina (Nielsen et al. *2011*). Socioeconomic and race/ethnicity have also been studied as potential explanatory factors. The proportion of women with an intact uterus at the age of 70 was found to be lower in less affluent areas in Australia (Beckmann et al. *2003*). In the USA, women from households with income below $35,000 and women in the Medicaid program were less likely to get laparoscopic hysterectomy (Abenhaim et al. *2008*). The same study found that White women were more likely to get a laparoscopic hysterectomy than any other ethnic group or minority.

However, interest has been centered on supply-side factors (Domenighetti et al. *1988*). The dramatic differences found in a recent OECD cross-country comparison (a more than threefold difference) (McPherson et al. *2013*) and the evidence from the Netherlands of a significant decline since 1995 (25 %) in the number of interventions performed for bleeding disorders (Hanstede et al. *2012*) support the importance of supply-side factors. Evidence from Denmark has shown that the volume of vaginal hysterectomies was independent of the total number of interventions performed at the hospital (Nielsen et al. *2011*), ruling out “overall surgical intensity” as a possible explanation. In the USA, Jacoby found a twofold variation in the use of bilateral salpingo-oophorectomy (BSO) at the time of hysterectomy for benign conditions, along with a dramatic 11-fold difference depending on whether the surgical approach was vaginal, laparoscopic, or abdominal (Jacoby et al. *2009*).

There is also some evidence of variation in the outcomes of surgery; despite a significant improvement in outcomes related to increases in the number of performed laparoscopic hysterectomies or surgical experience (up to 125 procedures), individual surgical skills still constitute an independent risk factor for blood loss and operating time (Twijnstra et al. *2012*).

Prostatectomy in Prostate Cancer

Unlike C-section or hysterectomy in uterus cancer, the effectiveness (benefit-harm balance) of prostate cancer prostatectomy is uncertain, particularly for low-risk cancers and low-volume providers (Wilt et al. *2008*; NICE *2008*). In Spain, the rate of prostatectomy in prostate cancer is 5.4 per 10,000 inhabitants and shows the largest ratio of geographical variation among elective procedures – up to a 7.7-fold difference (Peiró et al. *2009*). In the US Medicare population, the rate of prostatectomy is as high as 16.8 interventions per 10,000 inhabitants – with a 3.4-fold difference across regions (Data taken from the Dartmouth Atlas of Health Care website). Demand-side factors explaining variation have been frequently described. Older men, or men with more comorbidities, are less likely to get radical surgery (Oliver et al. *2003*; Nambudiri et al. *2012*). In the USA, Black men were less likely to get any surgical treatment, either radical prostatectomy (Nambudiri et al. *2012*), minimally invasive radical prostatectomy (Trinh et al. *2012*), or pelvic lymph node dissection (Hayn et al. *2011*). However, variation in the time "from diagnosis to surgery" among Black and Caucasian men was associated with demographic and clinical variables rather than race (Bañez et al. *2009*). Among supply-side factors, the number of high-volume hospitals and surgeons in the area and the number of prostate-specific antigen (PSA) tests performed have been suggested as associated factors (Peiró et al. *2009*). In fact, quite consistently, individuals living in wealthier urban areas (i.e., areas with more supply and easier access to PSA testing) are more likely to be exposed to prostatectomy in Australia (Hayen et al. *2008*), Spain (Peiró et al. *2009*), and England (Oliver et al. *2003*).

Cardiac Revascularization Surgery

Percutaneous coronary intervention (PCI) and coronary artery bypass graft (CABG) have been the subject of many variation analyses, most of them in the USA, where rates are more than double the median rate of the other OECD countries (OECD *2011*). The two interventions, both highly effective in treating ischemic disease and preventing secondary events, are experiencing a different evolution. For the last two decades, overall PCI rates have increased, although a slight decline has been observed since 2004. The use of CABG, however, started to decline in the mid-1990s with a steady 5 % decrease between 2001 and 2009 (Riley et al. *2011*).

Certain demand-side factors have been examined in an attempt to explain unwarranted variation. Recent literature on gender shows negligible or nonexistent sex differences in utilization (Meyers et al. *2009*). In fact, the increase in PCI use starting in 1988 has been similar in both genders after age standardization (Movahed et al. *2009*). Along the same lines, PCI procedural success rates, number of vessels attempted, and percentage of drug-eluting stent behaved similarly gender-wise in the USA (Thompson et al. *2006*). Conflicting results have been found with regard to outcomes. Whereas a study in the USA found female gender to be an independent predictor of in-hospital mortality after revascularization (Saleh et al. *2005*), other studies did not find any gender-related differences in major adverse coronary events (Thompson et al. *2006*; Aguado-Romeo et al. *2007*).

Race and ethnicity have been studied largely in the USA. Some studies have noted that Black and Hispanic patients, particularly Black women, were less likely than White patients to receive

revascularization (Cram et al. *2009*; Kamble and Boyd *2008*). Other studies, though, found race-related disparities in CABG utilization but not in PCI (Caillier *2006*). African-Americans who underwent PCI were also less likely to receive drug-eluting stents (Hannan et al. *2007*), and referrals to rehab after PCI were more frequent in Whites, particularly in low-referral hospitals (Aragam et al. *2011*). However, the magnitude of the differences has been falling since the late 1970s (Brown et al. *2008*), and no racial disparities have been observed regarding the increased use of PCI over time (Movahed et al. *2009*). In the case of CABG, off-pump interventions were more likely to be performed in Black patients, but only in the case of low-volume surgeons (Mukamel et al. *2007*). Differences in outcomes after receiving revascularization are also present. Blacks (as compared to all other patients) experienced higher fatality rates and rates of major adverse cardiac events after PCI (Gaglia et al. *2009*; Napan et al. *2010*). However, Black patients experienced a greater mortality reduction when receiving CABG in high-volume centers (Kim et al. *2008*).

Studies of social gradient as a demand-side factor have been published recently. Cardiovascular procedures – angiography, PCI, and CABG – showed lags in diffusion according to socioeconomic status, with early adoption in patients living in better-off areas in Australia (Korda et al. *2011*). In the USA, Medicaid patients and uninsured patients were less likely to receive drug-eluting stents (Hannan et al. *2007*; Gaglia et al. *2009*) or see high-volume providers (Bao and Kamble *2009*). Various supply-side factors have been proposed to explain variations in utilization and outcomes. In the USA, patients with ST segment elevation myocardial infarction (STEMI), living in low-population urban areas, were less likely to receive primary PCI (Kilbourne et al. *2011*).

Hospital characteristics have been used to explain variation in procedure choice and rates. Alter et al. introduced the concept of "invasive hospitals" (hospitals with on-site revascularization) and found that patients admitted to those hospitals were more likely to receive PCI than CABG in Canada (Alter et al. *2003*). In a study of Medicare patients, higher densities of specialists explained higher diagnostic catheterization rates which, in turn, explained higher revascularization rates (Hannan et al. *2006*). Most recently, hospital referral regions were found to explain up to 66 % of the variation in CABG rates (Quin et al. *2011*). In Europe, teaching hospitals were more likely than nonteaching hospitals to perform PCI (Gabriel Steg et al. *2003*). Along the same lines, density of regional resources in Japan explained disparities in the use of PCI on patients with Acute Myocardial Infarction (AMI) (Noguchi et al. *2008*).

With regard to ownership, public, as opposed to private, hospitals in Italy have experienced an increase in the use of PCI along with a concurrent decline in the use of CABG (although CABG rates were observed to increase in private hospitals) (Grilli et al. *2007*). As well, public hospitals have been shown to be more restrictive in the use of drug-eluting stents (Grilli et al. *2007*; Gaglia et al. *2010*). In addition, physicians' training and environment have been shown to play a role. In Ontario, Canada, planned (non-emergent) interventions for multivessel disease accounted for most of the variation. This was particularly attributed to the recommendation provided by the physician performing the diagnostic catheterization within a particular "treating culture." In fact, the PCI/CABG ratio varied up to threefold across hospitals in Canada (Tu et al. *2012*). The individual surgeon was also the main predictor when deciding whether to use drug-eluting stent in Scotland (Austin et al. *2008*). In the USA, several focus groups found a number of emotional and psychological factors driving primary care physicians to refer patients to elective PCI regardless their potential benefit on outcomes (Lin et al. *2008*).

Regarding outcomes, low-volume centers and individual surgeons have been identified as independent factors in predicting mortality in the USA (Mukherjee et al. *2005*). In addition to volume, surgeon perioperative practices might explain differences in mortality in CABG (Likosky et al. *2012*). Work organization (hospital complexity) might also explain differences in outcomes, beyond volume,

in both PCI and CABG. “Door-to-balloon” times varied noticeably across hospitals performing PCI in England and Wales (West et al. *2011*). Finally, mortality after CABG has been observed to be higher if performed after 4 p.m. and on weekends (Coumbe et al. *2011*).

Knee and Hip Replacement

Both knee and hip replacement procedures have been found to be effective options for reducing severe pain and disability, although it is uncertain whether less appropriate patients benefit from these interventions (Quintana et al. *2006*). Knee and hip replacements have been the subject of interest in numerous studies, both within and across countries. For instance, OECD’s *Health at a Glance* biennial report uses utilization rates for both procedures as a measure of system activity: in 2009 hip replacement rates ranged from 8 per 100,000 inhabitants in Mexico to 296 per 100,000 inhabitants in Germany, and knee replacement rates ranged from 3 per 100,000 inhabitants in Mexico to 213 per 100,000 inhabitants in Germany (OECD *2011*). In addition to wide variation between countries, there is evidence from the USA that the volumes of both primary and repeat hip and knee replacement procedures have been increasing (Kurtz et al. *2009*; Iorio et al. *2008*).

With regard to demand-side factors, age distribution was identified as the main driver of variation in rates in Australia (Dixon et al. *2006*) and the UK (Judge et al. *2009*), with a decline in patients aged 80 and older. There is conflicting evidence regarding gender differences. Whereas in some studies men were more likely to get replacement surgery (Hawkins et al. *2011*), in others the reverse was seen (Judge et al. *2009*). The highest variation in rates has been found to occur among male patients (Hanchate et al. *2008*) regardless of race (Skinner et al. *2003*). Socioeconomic status was also found to be an underlying factor in several studies. Patients living in lower-income or minority neighborhoods were less likely to receive knee or hip replacement in the USA (Hawkins et al. *2011*; Rahman et al. *2011*). However, this trend only held for hip replacement in the UK (Judge et al. *2009*). At the individual level, individuals with lower socioeconomic status in Canada were observed to have less access to a surgeon consultation and to joint arthroplasty (Rahman et al. *2011*), and patients with lower levels of education and income waited longer in hip replacement waiting lists in the UK (Laudicella et al. *2012*).

Finally, several American studies have addressed the impact of race or ethnicity on variations in joint surgery. Whites receive a larger number of knee replacement than Blacks (MMWR *2009*) or other racial and minority groups, independent of disease prevalence, disability, insurance status, and social gradients (Irgit and Nelson *2011*; Bang et al. *2010*). Stratifying by age group, differences associated with race were found to occur only in those aged 65 years and older (Dunlop et al. *2008*). These ethnic variations have been connected to differences in perception of benefit, lack of personal experiences, and trust (Suarez-Almazor et al. *2005*).

Although in the last decade the focus has been on demand-side factors, several studies have also addressed the influence of supply-side factors. Certain systemic factors, such as distance to hospital, have not been shown to have much of an effect on surgery rates (Judge et al. *2009*). However, one American study found that rural populations were more likely to receive joint surgery than urban populations (Francis et al. *2009*). Recent research in Spain has shown that differences in the eligibility criteria applied by physicians in decision-making have been responsible for the number of procedures performed as well as their level of appropriateness (Cobos et al. *2010*). A study conducted in Australia found a noticeable disparity in surgery indications across centers, highlighting either differences in physician decisions or differences in capacity (Ackerman et al. *2009*). Along similar lines, a recent study on hip arthroplasty in Finland identified a decision-making factor associated with variation, particularly in small orthopedic practices (Mäkelä et al. *2010*). Finally, with regard to

outcome variation, several studies have shown that higher hospital and individual surgeon volumes were associated with reduced operating times and therefore fewer postoperative complications (Ong et al. *2009*; Tomek et al. *2012*).

Lessons from the Literature

Some conclusions can be drawn from this targeted review of the latest evidence on variations in elective surgery:

- The scope of variation in elective surgery seems to be wide, and, in most cases, it goes hand in hand with an increase in procedure rates over time.
- The variation in outcomes from procedures seems to also be wide although it is interesting to note that the number of studies examining outcomes is limited.
- In studies examining factors on the demand-side, the focus appears to be placed on age, sex, and race and, less frequently, on education, income level, and a willingness to consume health care. The role of preferences and their interaction with the other demand factors seems to seldom be addressed in these types of studies. There is a strong positive association between "affluence" (individual or contextual) and rates of C-section. The extent to which this phenomenon stems from women's preferences has been insufficiently explored.
- Supply-side factors tend to encompass physician and provider characteristics. Studies of the effects of organizational mechanisms linked to funding schemes or the territorial distribution of providers are, however, notably missing.
- Discussions of system factors appear to be absent from the literature.

These observations afford us the opportunity to reflect on the limitations of country – or even local – scope of investigations that has hitherto been the norm in the analysis of variations. The more homogeneous the terms of comparison, the less feasible it is to determine whether the system and organization arrangements in place are behind the observed variation in utilization rates and to what extent (how much of the systematic variation is attributable to them). This consideration might be especially relevant from the policy-making point of view.

Thus, cross-country comparisons are much needed if researchers wish to add to the limited body of empirical knowledge on how within-country variations are underpinned by the specific characteristics of the system framework in which patients, physicians, and providers operate.

Interpreting Variation in Elective Surgery

The interpretation of procedure utilization rates and their variation entails a judgment as to whether high utilization rates are deemed to be good or bad. Obviously, such a valuation is highly dependent on the specific procedure. The pioneering Dartmouth Atlas initiative coined the distinction between effective care, preference-sensitive care, and supply-sensitive care to guide the interpretation of the analyses.

This classical taxonomy of procedures might be less universally applicable in countries where health systems provide publicly funded universal coverage for a basket of comprehensive benefits, and organizational and professional incentives differ from those in the USA. While the effective care category is self-explanatory, supply-sensitive and preference-sensitive care require clarification. Patients may differ in their preferences regarding elective surgery, and the decision to prescribe

elective surgery is often amenable being influenced by professional "preferences," which in turn may be driven by knowledge, training, organizational inertia, and local availability of resources. Therefore, the classic categories could be adapted to better suit the context of a National Health Service. The proposed taxonomy highlights the nature of the procedure irrespective of the factors affecting its utilization. For example, in the Atlas of Variations in the Spanish National Health Service, a project inspired by the Dartmouth Atlas of Health Care (Bernal-Delgado et al. *2014*), elective surgery was categorized as (1) effective surgery, (2) effective surgery with uncertain benefit-risk balance in non-average patients, and (3) low-value surgery.

In the Spanish Atlas project, effective surgery was equivalent to the classic Wennberg definition and encompassed surgeries such as hip fracture repair and colectomy in colorectal cancer. The second category covers effective surgery performed in non-eligible patients (e.g., knee replacement in patients with mild pain, stiffness, or disability or PCI in patients with stable angina). Finally, the low-value group includes ineffective surgery that is nevertheless widely used (e.g., radical prostatectomy in low-risk prostate cancer or tonsillectomy in children) or surgery with more cost-effective alternatives (e.g., hysterectomy instead of medical treatment as the first treatment choice for uterine bleeding, radical mastectomy instead of lumpectomy as the first choice for early stage breast cancer). These three categories have been observed to be useful for understanding unwarranted variation and informing policy change in several European Union (EU) countries (ECHO www.echo-health.eu) and will be used in this section to help in the interpretation of variations in elective surgery.

Before delving into the application of these categories to elective surgery variation, it is worth recalling that, as in other domains of care, unwarranted variation requires two conditions: it needs to be systematic (i.e., not amenable to randomness and persistent over time) and unrelated to differences in population illness or patient needs.

The analysis of geographical or regional variations yields information on differential population exposure to certain types of care, that is, it stems from an ecological approach. Variation across patients/providers, on the other hand, requires a precise definition of patients at risk, interventions, and end points. Therefore, while interpreting variations at the patient-provider level is straightforward, inference from ecological/geographical variation to individual's experience (i.e., *ecological fallacy*) will require additional assumptions to avoid misinterpretations of results.

Building on this framework, the following paragraphs illustrate the specific issues for interpreting geographic variations in elective surgery.

Interpreting Geographic Variations on Elective Surgery

When interpreting unwarranted variation in the rates of an elective surgery, high population rates have frequently been considered as indicative of overuse, whereas low rates traditionally have been considered to indicate underutilization. The rationale is as follows. Take two areas, X and Y, with the same burden of disease (e.g., a prevalence of osteoarthritis of 30 cases per 10,000 inhabitants) and without barriers to access of care. Area X performs 28 interventions per 10,000 inhabitants and area Y, 101 interventions per 10,000 inhabitants, a 3.6-fold difference. Surgeons in the low-rate area (X) will plausibly have lower sensitivity and higher specificity when selecting eligible patients than their colleagues in area Y. Let us assume sensitivity of 60 % and 70 % and specificity of 99.9 % and 99.2 %, respectively.

As shown in Table 3, surgeons from a low-rate area properly identify and treat 18 out of 30 patients, with 10 false-positive cases (36 % overuse) and 12 false-negative patients (40 % underuse). However, in the high-rate area, there is a sizable increase in sensitivity along with a tiny decrease in specificity: surgeons would adequately identify and treat a slightly larger number of cases (up to 21), but the

number of false-positive cases is eightfold higher (up to 80 cases out of 101 intervened, 80 % overuse), along with a slight decrease in the underuse rate to 33 % (nine false-negative patients).**Table 3**

Elective surgery (e.g., knee replacement) in low and high intervention rate areas: effects of overuse and underuse

	Area X (low rate)					**Area Y (high rate)**		
		Need				**Need**		
		Yes	No			Yes	No	
Surgical decision	*Yes*	18	10	**28**	*Yes*	21	80	**101**
	No	12	9,960	9,972	*No*	9	9,890	9,899
		30	9,970	10,000		30	9,970	10,000

Modified from: Peiró S. Variaciones en la Práctica Médica y utilización inadecuada de tecnologías. en Difusión de Nuevas Tecnologías Sanitarias y Políticas Públicas. Beatriz González López-Valcárcel Ed. Masson, Barcelona 2005

Although, as empirically observed, overuse in a high-population rate area is more likely than underuse in a low-population rate area, pronouncing a rate to be overuse or underuse requires additional reflection. Essentially, the argument has to take into account the type of service under study and whether it is effective care, uncertain benefit-risk balance in the non-average patient, or lower-value care. In general terms, the following statements hold true:

1.

When interpreting variation in effective care (e.g., colectomy in colorectal cancer), given no barriers to access, differences across areas will reflect differences in population illness.

2.

When observing variation in services with uncertain benefit-risk balance in the non-average patient (e.g., knee replacement, PCI), underuse will be possible when barriers to access are in place (e.g., ability to pay, door-to-balloon time, economic gradient, ignorance about the relative benefits), while overuse will likely occur in the presence of volume incentives (e.g., fee for service).

3.

When analyzing variation in low-value care (e.g., radical prostatectomy in low-risk prostate cancer), all rates are inappropriate since the category refers to both ineffective care and effective care used in inappropriate indications.

Furthermore, for any elective procedure categorized as having uncertain benefit-risk in the non-average patient category, the patients treated comprise three groups: the average patient who will

clearly benefit (effective care), those who are ineligible for the intervention (low-value care), and a third group for whom the risk-benefit balance is uncertain. An example is presented below.

The decision to perform knee replacement is best informed by a patient's **Western Ontario and McMaster Universities Arthritis Index (WOMAC)** score, a measure based on their self-reported level of pain, stiffness, and disability that reliably predicts the potential benefit from surgery. Whereas providing the intervention to patients with high scores could be considered effective care, those patients with low scores should not be exposed to knee replacement (low-value care). Intermediate scores represent uncertainty with regard to the benefit-risk balance. A study performed in Spain (Espallargues *2005*) obtained the WOMAC score of patients already in the waiting list for joint replacement, confirming a bell-shaped distribution: a significant proportion of patients fell in the intermediate range denoting uncertain benefit, while a smaller number of patients fell into the tails of the distribution, with scores denoting high and low probabilities of success.

This brings us to the question of how to make sense of utilization rates in procedures in the second group of the aforementioned taxonomy (variation in services with uncertain benefit-risk balance in the non-average patient: shall high rates of knee replacement be considered as overuse and low rates as underuse?) A plausible hypothesis is that high rates indicate overuse, particularly when "do-more" incentives are in place (fee-for-service, productivity-enhancing programs, increased availability of surgical theater hours, etc.). But drawing such a conclusion would require knowing the distribution of "lower-value/uncertain/effective" indications among the patients treated in a particular area. The same argument applies when it comes to hypothesizing that low rates are an indication of underuse, especially when access barriers or lagged adoption is at play. In this respect, unusual rates should be seen as a signal calling for further analysis of the outlying regions and require additional information.

Rate and Variation: Consistency Over Time

One of the basic requirements for variation to be considered "systematic" as opposed to spurious is persistence over time. In the case of elective surgery, this is of particular interest due to the continuous evolution of technology (e.g., new diagnostic tests, new procedures, new surgical techniques, new instruments) which triggers the effects associated with early vs. lagged adoption (i.e., implementation and learning curves, substitution). Some examples of this evolutionary nature include conservative vs. nonconservative breast cancer surgery, PCI vs. CABG, or laparoscopic hysterectomy vs. vaginal hysterectomy.

Therefore, the analysis of variation in surgical procedures experiencing technological advance requires further consideration about changes in both utilization rates and variation. A trend of increasing utilization of an effective procedure will not mean the same as an increase in the rate of a lower-value procedure that has been deemed obsolete. Similarly, the interpretation of a decline in variation differs in the two cases. Let us consider breast cancer surgery and spinal fusion as case studies to elaborate on this point.

Conservative breast cancer surgery (i.e., lumpectomy and quadrantectomy), together with radiotherapy, has been shown to be as effective as nonconservative surgery, proving to be safe in the long term with reduced regional lymphatic side effects. Adoption requires both specific training and the availability of radiotherapy. In Spain, the technique has progressively spread over the last decade, resulting in a moderate increase over time as well as the expected reduction in variation (Fig. 3).

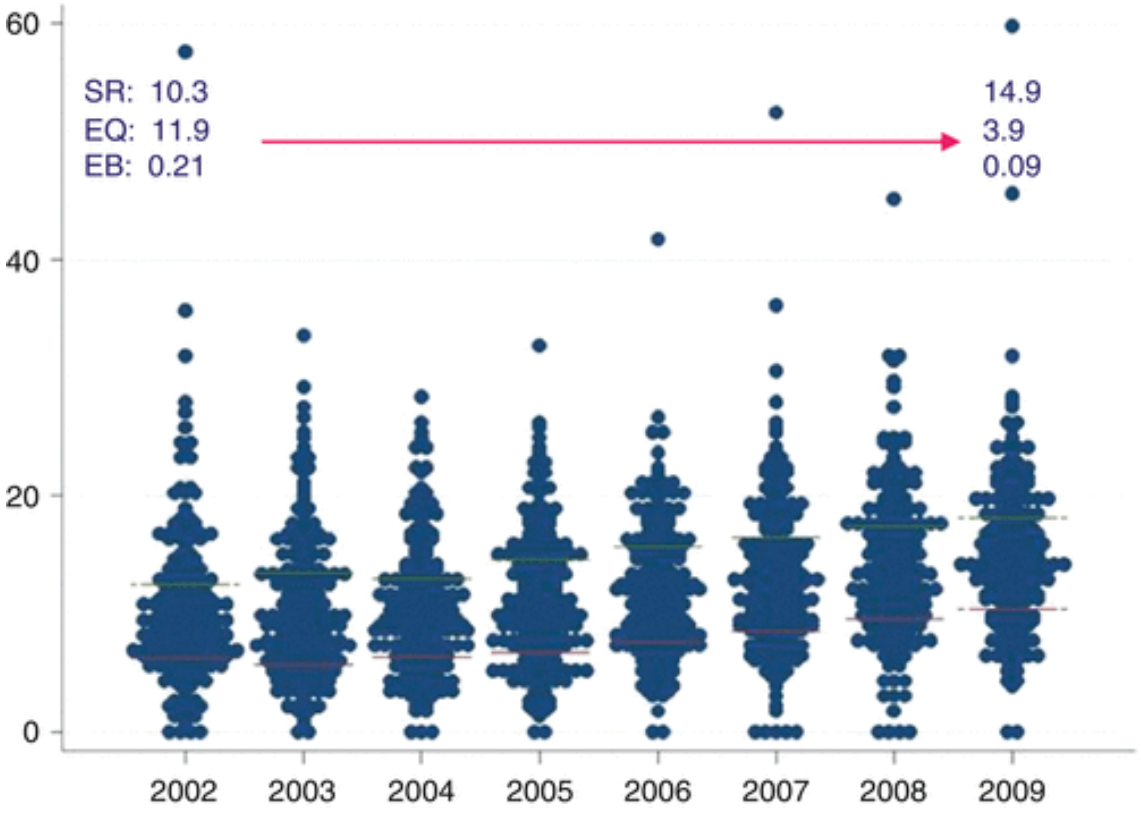

Fig. 3

Conservative breast cancer surgery in Spain, 2002–2009

In contrast, spinal fusion in patients with persistent low back pain is a “low-value” procedure, with existing effective and safer treatment alternatives (i.e., conservative treatment) (NICE *2009*). In Spain, spinal fusion variation declined noticeably over time; however, the average rate has increased slightly (Fig. 4).

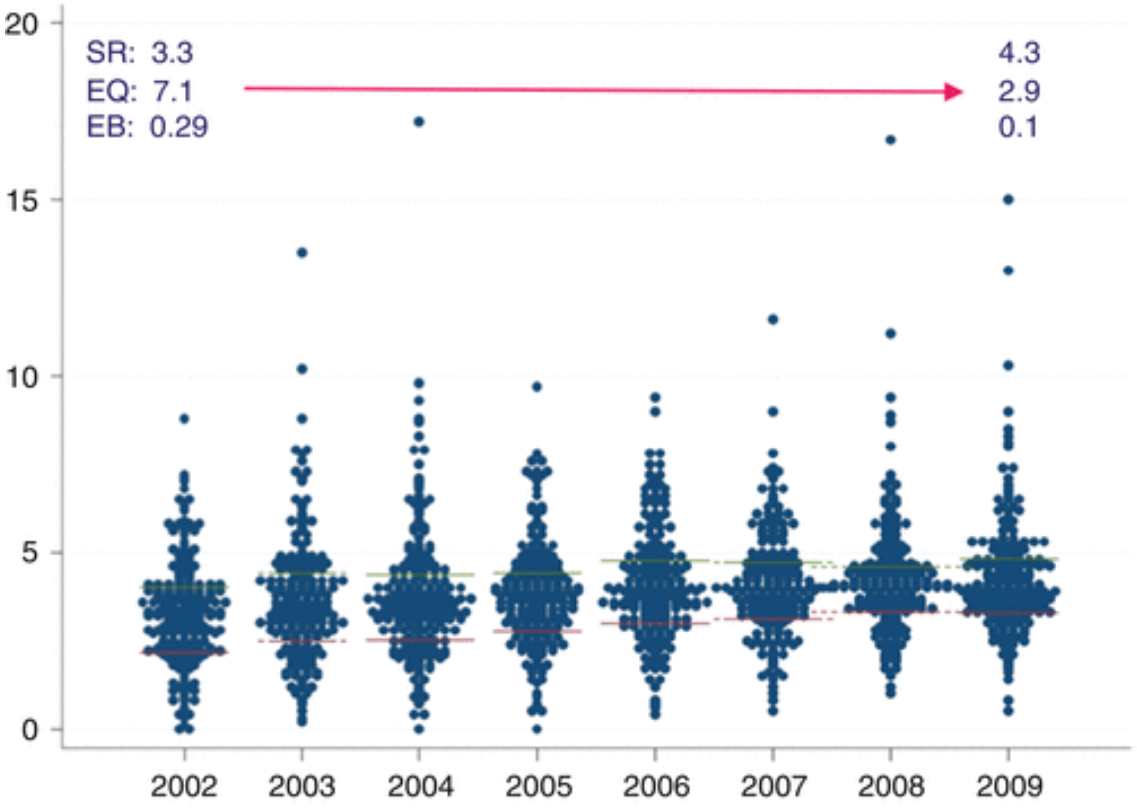

Fig. 4
Spinal fusion in Spain, 2002–2009

A reduction in the variation of conservative breast surgery (along with an increase in the rate) must be understood as a desirable development. However, a reduction of the variation in spinal fusion has to be viewed as an undesirable result, if rates are observed to increase over time. Therefore, a reduction in the variation in utilization has limited meaning without taking into consideration the nature of the service (i.e., low-value/uncertain risk-benefit/effective) and the direction of the change in rates.

Interpretation of Substitution of Technologies

A typical phenomenon seen when analyzing elective procedures, whether using cross-sectional or time series data, is the substitution of equally effective services. Some examples are PCI rates vs. defined daily dose of drugs effective in preventing secondary events on ischemic disease, CABG vs. PCI in non-multivessel disease, and conservative vs. nonconservative breast surgery. In these cases, areas with low rates should not be considered to be underserved areas before confirming concurrent low rates of the alternative treatment. A proper estimation of the shared effect of both alternatives requires specific methodology. For that purpose, shared component modeling might help us understand how concurrent phenomena (utilization of procedures) interact in a specific geographic area and over time (Ibañez-Beroiz et al. *2011*).

A Caveat in Interpreting Lower-Value Care

The general principle in dealing with lower-value care is that the most desirable situation is the lowest rate. Except in the case of obsolete technologies, there are always some appropriate indications for

patients who might benefit from lower-value interventions. For instance, discectomy with spinal fusion should be offered when conservative treatment fails, and prostatectomy in prostate cancer should be offered in medium-risk localized prostate cancer.

The statement "the lower the rate, the better" assumes that regional differences in factors such as risks, specific conditions, and individual burden of disease are reduced as a consequence of the *law of large numbers*, that is, eligible patients for the lower-value interventions are distributed randomly across areas. This assumption might not always be true, particularly when the areas are very small, or the procedures under study are rare. Prior to interpreting a rate of lower-value care, it is important to judge whether the assumption of a random distribution of risks is reasonable.

Lessons from Unwarranted Variation in Elective Surgery

The existence of unwarranted variation, that is, systematic variation not justified by differences in populations or patients' needs, is relevant for policy-making: (1) people might be underserved depending on the place where they live; (2) patients should co-own decisions, particularly when uncertainty is the rule; (3) unwarranted variations involve high opportunity costs; and (4) clinical microsystems should be involved in reducing unwarranted variation in care.

Underuse of Effective Surgery

After ruling out the difference within burden of disease, areas with systematically low rates of effective interventions might be underserved. Two possibilities should be explored: access barriers (geographical, cultural, socioeconomic, financial, etc.) and time-to-adoption delays (lack of specific equipment, insufficient training, disbelief about the relative merits of the "new" technology, even ignorance about its superiority, etc.).

In the first case, expensive health plans or high co-payments linked to accessing effective care might be the case of barriers, particularly in fragile household economies. Physical distance to the provider may also play a role, calling for organizational enhancements (e.g., reducing time to PCI by improving urgent transportation from rural areas).

In the second case, long time to adoption, reducing the gap between evidence and practice is considered to be a priority. Synthesis and dissemination of new evidence, audit and feedback, checking out own practice, clinical guidelines development and implementation, and training programs improving expertise are some of the tools available for tackling this sort of underuse. But the most important lever might be the organizational context in which these individual strategies are implemented –"smart" organizations, where incentives are aligned to maximize the use of knowledge with a view to obtaining the best outcomes, have been proven effective in reducing the knowledge gap (Bernal-Delgado *2008*).

Patients Should Be Involved in Decisions

The benefit-risk balance of most major elective surgeries is for non-average patients. Evidently, each patient is expected to be sensitive to this lack of certainty about the advantages or disadvantages of the procedure in his or her particular case. Given the lack of prescriptive clinical criteria, only empowered patients provided with sound information could bring in the relevant elements to bear in making decisions affecting their health.

Seminal evidence of the influence of sharing appropriate information on reducing unwarranted variation came from Europe and the USA (Domenighetti et al. *1988*; Wennberg et al. *1999*) and opened the door to managing uncertainty through what has been coined *shared decision-making*. A recent study provides additional evidence of the potential of this strategy, showing a reduction in unneeded hospital admissions, dubious elective surgeries, and care costs (Veroff et al. *2013*). Pioneered by the Informed Medical Decisions Foundation (http://informedmedicaldecisions.org/), there are currently numerous shared decision-making resources all over the world. Table 4 provides some examples. Some of the initiatives stem from the academic sector and devote a lot of attention to developing, testing, and improving decision tools (Ottawa, Quebec, Cardiff, Dartmouth). Others are meant to implement shared decision-making. These include two care providers (Dartmouth-Hitchcock and Mayo Clinic), a large for-profit initiative (Health Dialog), and two examples of public institutional efforts from the US Department of Health and Human Services http://www.effectivehealthcare.ahrq.gov/index.cfm/tools-and-resources/patient-decision-aids/, and the English National Health Service. Lastly, the table includes some international initiatives aiming at making relevant knowledge available (Cochrane and Med-Decs) and building international standards (IPDAS).**Table 4**

Experiences on shared decision-making and patient aids

Country	Institution	Description	Access
Canada (1995)	Ottawa Hospital Research Institute – affiliated to University of Ottawa	Group designing and testing decision aids and training programs for patients and health practitioners	http://decisionaid.ohri.ca/index.html
Canada (2006)	Laval University	"Canada Research Chair in Implementation of Shared Decision Making in Primary Care"	http://decision.chaire.fmed.ulaval.ca
Wales (2007)	"Decision Laboratory" at Cardiff University	The "Decision Laboratory" group develops and evaluates decision support interventions on a not-for-profit basis	http://www.decisionlaboratory.com/
USA (2000)	The Dartmouth Institute for Health Policy and Clinical Practice	Devoted to the study of patients' health-care decision-making and the development and	http://tdi.dartmouth.edu/initiatives/informed-choice-dale

		implementation of policy- and practice-based solutions	
USA (1997)	Health Dialog	Private for-profit company founded to bring to practice the groundbreaking research on unwarranted variations and patient preferences by The Dartmouth Institute for Health Policy and Clinical Practice and the Informed Medical Decisions Foundation and others	http://www.healthdialog.com/Main/default
USA (1999)	**Center for Shared Decision Making at Dartmouth-Hitchcock**	First center in the USA dedicated to encouraging doctors and patients to practice shared decision-making	http://patients.dartmouth-hitchcock.org/shared_decision_making.html
USA (2010)	Shared Decision Making National Resource Center at Mayo Clinic	The center advances patient-centered medical care by promoting shared decision-making through the development, implementation, and assessment of patient decision aids and shared decision-making techniques	http://shareddecisions.mayoclinic.org/
USA (2009)	Agency for Healthcare Research and Quality	Patient decision aids are designed for patients with specific conditions to help them think about what is important	http://www.effectivehealthcare.ahrq.gov/index.cfm/tools-and-resources/patient-decision-aids/

		to them when talking with their clinician about treatment options	
England (2012)	National Health Service	The Shared Decision Making program is part of the Quality, Innovation, Productivity and Prevention (QIPP). Since 2012 it is aiming to embed the practice of shared decision-making among patients and those who support them and among health professionals and their educators	http://www.rightcare.nhs.uk/index.php/shared-decision-making/about-the-sdm-programme/
International	International Patient Decision Aids Standards Collaboration	The IPDAS collaboration developed an instrument named IPDASi aimed at assessing the quality of patient decision support interventions	http://www.ipdasi.org/
International	Med-Decs at Radboud University Nijmegen Medical Centre	Med-Decs is a still ongoing European project aimed at building a worldwide database of decision aids	http://www.med-decs.org/
International	Cochrane Consumers and Communication Review group at La Trobe University	As part of the Cochrane Collaboration, the group coordinates the preparation and publication of systematic reviews of interventions which affect the way people interact with	http://cccrg.cochrane.org/

		health-care professionals, services, and researchers	

High Opportunity Costs

Both the overuse of procedures and utilization of lower-value care can be easily understood as misused resources, carrying a tremendous opportunity cost for patients and society: on the patient side, failure to receive the better care alternative and exposure to unnecessary risks and from the societal perspective, the inefficient allocation of resources intended to maximize health and welfare. To give a flavor of the potential magnitude of those opportunity costs, let us take another look at the utilization of spinal fusion (Fig. 4). In 2007, areas in the 95th percentile of utilization performed almost four times more spinal fusions as areas in the 5th percentile. How much money could have been freed (and eventually reinvested in a better alternative) if areas in the 95th percentile had behaved as the best performers – areas in 5th percentile?

A formal exercise was carried out across the 199 health-care areas in Spain, assessing some lower-value care – proctologic surgery, knee replacement revision, tonsillectomy, and spinal fusion (Ridao-López et al. *2012*); Table 5 shows the extremal quotient and the "excess cost" for each of the procedures in a yearly basis. "Excess cost" ranged from €22,147 million in the case of arthroplasty revision to €129,727 million in the case of proctologic surgery.**Table 5**

Opportunity costs in four lower-value health-care procedures

	$EQ_{5–95}$	Unitary cost (€)	Excess cost (annual-M€)
Proctologic surgery	3.10	8,665	**129,727**
Arthroplasty revision	4.6	9,925	**22,147**
Tonsillectomy	5.8	7,525	**67,662**
Spinal fusion	**3.8**	**18,229**	**115,856**

Note: $EQ_{5–95}$ represents the cost ratio between regions in the 95th vs. 5th percentiles. Unitary cost (€) represents the actual cost of each procedure using Spanish tariffs. Excess cost represents the annual cost attributable to excess cases in health-care regions with costs that are higher than the benchmark region, specifically regions at or below the 5th percentile. Excess cost acts as a proxy for the opportunity costs faced by a society

Several institutional efforts around the world, notably the National Institute for Health and Care Excellence (NICE) in the UK, (http://www.nice.org.uk/usingguidance/donotdorecommendations/index.jsp) and others in Canada, Australia, Italy, and Spain (Bohmer et al. *2001*; Elshaug et al. *2007*; Elshaug et al. *2009*; Ibargoyen-Roteta et al. *2010*; Nuti et al. *2010*) as well as professional documents such as *Choosing Wisely* (http://www.choosingwisely.org/) or *Too Much Medicine* (http://www.bmj.com/too-much-medicine), are meant to deal with low-value care; some of them have a particular

emphasis on elective surgery. Two key steps in reducing low-value care, proposed by García-Armesto et al. (García-Armesto et al. *2013*), are the following:

Identifying those technologies ineffective in their usual indications or less effective than alternatives

Dropping them from the benefits basket or making them subject to avoidable copayments

Restricting indications to certain types of patients (choice guided by evidence of positive benefit/risk balance)

Specifying and limiting the types of providers more suitable to offer each service (therefore substantiating indication becomes a requisite, discouraging irrelevant use)

Capping the frequency or length of treatments

Producing and making available guidance on a regular basis to reduce inappropriate use of procedures

Highlighting and tackling unwarranted variations in elective surgery (naming and "shaming" to prompt query and change)

Fostering best practices and improving coordination of care

Clinical Microsystems: An Effective Tool in Limiting Unwarranted Variation in Surgical Care

Unwarranted variations in rates of surgery and outcomes have been shown to be local phenomena as a consequence of the numerous decisions made by health-care professionals in the context of clinical microsystems. The involvement of those microsystems (namely, departments or pathways of care) is critical in reducing unwarranted variation. Some pioneering examples stem from the initiative of the former Agency for Health Care Policy and Research (AHCPR) through the Patients Outcomes Research Teams (PORT) (Salive et al. *1990*), the National Surgical Quality Improvement Program developed and run by the Department of Veterans Affairs (Khuri et al. *1998*), and the many lessons learned from Dartmouth's research on variations. These projects demonstrate the powerful effect of microsystems in reducing variations in surgical outcomes. Among them, three outstanding pioneering experiences are worth mentioning: the Northern New England Cardiovascular Disease Study Group (http://www.nnecdsg.org/), the Spine Patient Outcomes Research Trial (SPORT) (http://www.dartmouth.edu/sport-trial/), and the PORT on Benign Prostatic Hypertrophy and Localized Prostate Cancer (http://archive.ahrq.gov/clinic/medtep/bphport.htm#bphpdis).

Since then, a plethora of microsystems has developed structured "research into practice" initiatives that focus on reducing unwarranted variations in surgery. Some examples include the American College of Surgeons through its National Surgical Quality Improvement Program (http://site.acsnsqip.org/); the Michigan Surgical Quality Collaborative, which involves 52 hospitals in the Midwestern USA (http://www.msqc.org/); the Surgical Care and Outcomes Assessment program, which is comprised of 50 hospitals in Washington state (http://www.scoap.org/); the National Surgical Quality Improvement Program in Canada (http://innovation.healthcouncilcanada.ca/); the surgical departments at Mayo Clinic (www.mayo.clinic/surgical-outcomes-program); and the Johns

Hopkins Center for Surgical Trials and Outcomes Research (CSTOR) (https://www.hopkinsresearch.org/).
This flow of North American initiatives has had a powerful impact throughout other parts of the globe. Similar initiatives have been deployed, starting with the pioneering European Coronary Surgery Study (Varnauskas *1988*). The most relevant examples arise from research collaborations or are based on the development of specific registries. Among the former, it is worth citing the International Surgical Outcomes Study (ISOS) (http://www.isos.org.uk/isos.php) and the IDEAL Collaboration (http://www.ideal-collaboration.net/); within the latter, notable examples include the registries run by the Nordic Arthroplasty Register Association (http://www.nordicarthroplasty.org/) and the National Vascular Registry headed by the Royal College of Surgeons of England (http://www.rcseng.ac.uk/surgeons).

Conclusion

Elective surgery utilization and its unwarranted variation are rich fields of exploration and are currently high-priority topics on governments' agendas. Their analyses can provide useful insights to guide tackling issues such as patient centeredness, the trade-offs between quality, efficiency, and equity in the context of financial sustainability of health systems, the enhancement of *value for money* strategies, and knowledge brokering and innovation mechanisms. The recent advent of cross-country comparisons anticipates an increase in demand for evidence concerning the impact of institutional arrangements and system frameworks on utilization and unwarranted variation and may enhance the policy relevance of such research.

References

General

Bernal-Delgado E. How can we improve effectiveness (quality) by reducing the gap between research and action? Gac Sanit. 2008;22 Suppl 1:19–26.
PubMed

Bernal-Delgado E, García-Armesto S, Peiró S, Atlas VPM Group. Atlas of variations in medical practice in Spain: the Spanish National Health Service under scrutiny. Health Policy. 2014;114(1):15–30.
PubMed

Bohmer G, Pain P, Watt C, et al. Maximising health gain within available resources in the New Zealand public health system. Health Policy. 2001;55:37–50.
PubMed

Elshaug AG, Hiller JE, Tunis SR, Moss JR. Challenges in Australia policy processes for disinvestment from existing, ineffective health care practices. Australia and New Zealand. Health Policy. 2007;4:23.

Elshaug AG, Watt AM, Moss JR, et al. Policy perspectives on the obsolescence of health technologies in Canada. In: Discussion paper Canadian Agency for Drugs and Technologies in Health for the Health Technology Strategy Policy Forum. CADTH. 2009. http://www.cadth.ca/media/policy_forum_section/Obsolescence%20of%20Health%20Technologies%20in%20Canada_Policy_Forum_e.pdf. Accessed 18 Apr 2013.

Espallargues M. Necesidades y priorización. Jornada sobre artroplastias: perspectivas clínicas, de gestión y de investigación en servicios sanitarios. Ministerio de Sanidad y Consumo y Red IRYSS. Madrid, 2 de junio 2005.

García-Armesto S, Campillo-Artero C, Bernal-Delgado E. Disinvestment in the age of cost-cutting sound and fury. Tools for the Spanish National Health System. Health Policy. 2013;32:180–85. doi:10.1016/j.healthpol.2013.01.007. Accessed 18 Apr 2013.

Glover JA. The incidence of tonsillectomy in school children. Proc R Soc Med. 1938;31(1219):95–112.

Ibáñez-Beroiz B, Librero-López J, Peiró-Moreno S, et al. Shared component modelling as an alternative to assess geographical variations in medical practice: gender inequalities in hospital admissions for chronic diseases. BMC Med Res Methodol. 2011;11:172.
PubMedCentral PubMed

Ibargoyen-Roteta N, Gutiérrez-Ibarluzea I, Asua J. Guiding the process of health technology disinvestment. Health Policy. 2010;98:218–26.
PubMed

Khuri SF, Daley J, Henderson W, Hur K, Demakis J, Aust JB, et al. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. National VA Surgical Quality Improvement Program. Ann Surg. 1998;228(4):491–507.
PubMedCentral PubMed

McPherson K, Wennberg JE, Hovind OB, et al. Small-area variations in the use of common surgical procedures: an international comparison of New England, England, and Norway. N Engl J Med. 1982;307:1310–4.
PubMed

McPherson K, Gon G, Scott M. International variations in a selected number of surgical procedures. OECD health working papers. 2013. doi:10.1787/5k49h4p5g9mw-en. Accessed 18 Apr 2013.

NICE. Prostate cancer: diagnosis and treatment. 2008. http://www.nice.org.uk/CG058. Accessed 18 Apr 2013.

NICE. Prosthetic intervertebral disc replacement in the lumbar spine. 2009. http://guidance.nice.org.uk/IPG306. Accessed 18 Apr 2013.

Nuti S, Vainieri M, Bonini A. Disinvestment for re-allocation: a process to identify priorities in healthcare. Health Policy. 2010;95:137–43.
PubMed

OECD. Health at a glance 2011: OECD indicators. OECD Publishing. 2011. doi:10.1787/health_glance-2011-en. Accessed 18 Apr 2013.

Ridao-López M, García-Armesto S, Peiró S, et al. Evaluación de la variabilidad geográfica de la práctica médica como herramienta de evaluación de políticas sanitarias. Presupuesto y Gasto Público. 2012;68:193–210.

Salive ME, Mayfield JA, Weissman NW. Patient Outcomes Research Teams and the Agency for Health Care Policy and Research. Health Serv Res. 1990;25(5):697–708.
PubMedCentral PubMed

Varnauskas E. Twelve-year follow-up of survival in the randomized European Coronary Surgery Study. N Engl J Med. 1988;319(6):332–7.
PubMed

Veroff D, Marr A, Wennberg D. Enhanced support for shared decision making reduced costs of care for patients with preference-sensitive conditions. Health Aff. 2013;32:285–93.

Wennberg JE. Small area analysis and the medical care outcome problem. In: Sechest L, Perren E, Bunker J, editors. AHCPR conference proceedings: research methodology strengthening causal interpretations of non-experimental data. Rockville: DHSS Publications; 1990. p. 90–3454.

Wennberg JE, Gittelsohn A. Health care delivery in Maine (I): patterns of use of common surgical procedures. J Maine Med Assoc. 1975;66:123–30.
PubMed

Wennberg JE, Barnes BA, Zubkoff M. Professional uncertainty and the problem of supplier-induced demand. Soc Sci Med. 1982;16(7):811–24.
PubMed

Wennberg JE, Cooper MM, et al. The quality of medical care in the United States: the Dartmouth Atlas of Health Care 1999. Chicago: American Hospital Publishing; 1999. p. 224–7.

Tonsillectomy

Erickson BK, Larson DR, St Sauver JL, et al. Changes in incidence and indications of tonsillectomy and adenotonsillectomy, 1970–2005. Otolaryngol Head Neck Surg. 2009;140:894–901.
PubMed

Fedeli U, Marchesan M, Avossa F, et al. Variability of adenoidectomy/tonsillectomy rates among children of the Veneto Region, Italy. BMC Health Serv Res. 2009;9:25.
PubMedCentral PubMed

Jacobs K, Jorissen M, Lemkens P. Current Belgian adenotonsillectomy practice: a survey among Belgian ENT specialists. B-ENT. 2010;6:83–90.
PubMed

Lock C, Wilson J, Steen N, et al. Childhood tonsillectomy: who is referred and what treatment choices are made? Baseline findings from the North of England and Scotland Study of Tonsillectomy and Adenotonsillectomy in Children (NESSTAC). Arch Dis Child. 2010;95:203–8.
PubMed

Materia E, Di Domenicantonio R, Baglio G, et al. Epidemiology of tonsillectomy and/or adenoidectomy in Italy. Pediatr Med Chir. 2004;26:179–86.
PubMed

van den Akker EH, Schilder AG, Kemps YJ, et al. Current indications for (adeno)tonsillectomy in children: a survey in The Netherlands. Int J Pediatr Otorhinolaryngol. 2003;67:603–7.
PubMed

van Staaij BK, van den Akker EH, Rovers MM, et al. Effectiveness of adenotonsillectomy in children with mild symptoms of throat infections or adenotonsillar hypertrophy: open, randomised controlled trial. BMJ. 2004;329:651.
PubMedCentral PubMed

Cesarean Section

Baicker K, Buckles KS, Chandra A. Geographic variation in the appropriate use of cesarean delivery. Health Aff. 2006;25:355–67.

Carayol M, Blondel B, Zeitlin J, et al. Changes in the rates of caesarean delivery before labour for breech presentation at term in France: 1972–2003. Eur J Obstet Gynecol Reprod Biol. 2007;132:20–6.
PubMed

Chen CS, Lin HC, Liu TC, et al. Urbanization and the likelihood of a cesarean section. Eur J Obstet Gynecol Reprod Biol. 2008;141:104–10.
PubMed

Clark SL, Belfort MA, Hankins GD, et al. Variation in the rates of operative delivery in the United States. Am J Obstet Gynecol. 2007;196:526. e1–e5.
PubMed

Fairley L, Dundas R, Leyland AH. The influence of both individual and area based socioeconomic status on temporal trends in Caesarean sections in Scotland 1980–2000. BMC Public Health. 2011;11:330.
PubMedCentral PubMed

Freitas PF, Drachler Mde L, Leite JC, et al. Inequalities in cesarean delivery rates by ethnicity and hospital accessibility in Brazil. Int J Gynaecol Obstet. 2009;107:198–201.
PubMed

Grytten J, Monkerud L, Sørensen R. Adoption of diagnostic technology and variation in caesarean section rates: a test of the practice style hypothesis in Norway. Health Serv Res. 2012;47:2169–89.
PubMedCentral PubMed

Hanley GE, Janssen PA, Greyson D. Regional variation in the cesarean delivery and assisted vaginal delivery rates. Obstet Gynecol. 2010;115:1201–8.
PubMed

Márquez-Calderón S, Ruiz-Ramos M, Juárez S, et al. Caesarean delivery in Andalusia, Spain: relationship with social, clinical and health services factors (2007–2009). Rev Esp Salud Publica. 2011;85:205–15.
PubMed

Hysterectomy

Abenhaim HA, Azziz R, Hu J, et al. Socioeconomic and racial predictors of undergoing laparoscopic hysterectomy for selected benign diseases: analysis of 341487 hysterectomies. J Minim Invasive Gynecol. 2008;15:11–5.
PubMed

Beckmann K, Iosifidis P, Shorne L, et al. Effects of variations in hysterectomy status on population coverage by cervical screening. Aust N Z J Public Health. 2003;27:507–12.
PubMed

Bottle A, Aylin P. Variations in vaginal and abdominal hysterectomy by region and trust in England. BJOG. 2005;112:326–8.
PubMed

Domenighetti G, Luraschi P, Casabianca A, et al. Effect of information campaign by the mass media on hysterectomy rates. Lancet. 1988;2:1470–3.
PubMed

Hanstede MM, Burger MJ, Timmermans A, et al. Regional and temporal variation in hysterectomy rates and surgical routes for benign diseases in the Netherlands. Acta Obstet Gynecol Scand. 2012;91:220–5.
PubMed

Jacoby VL, Vittinghoff E, Nakagawa S, et al. Factors associated with undergoing bilateral salpingo-oophorectomy at the time of hysterectomy for benign conditions. Obstet Gynecol. 2009;113:1259–67.
PubMed

Nielsen SL, Daugbjerg SB, Gimbel H, et al. Steering Committee of Danish Hysterectomy Database. Use of vaginal hysterectomy in Denmark: rates, indications and patient characteristics. Acta Obstet Gynecol Scand. 2011;90:978–84.
PubMed

Peiró S, Meneu R, Bernal-Delgado E. Effectiveness, variation and inequalities. Hysterectomies and prostatectomies due to neoplasm in Spain (2002–2004). Rev Esp Salud Publica. 2009;83:109–21.
PubMed

Ribeiro SC, Ribeiro RM, Santos NC, et al. A randomized study of total abdominal, vaginal and laparoscopic hysterectomy. Int J Gynaecol Obstet. 2003;83:37–43.
PubMed

Twijnstra AR, Blikkendaal MD, van Zwet EW, et al. Predictors of successful surgical outcome in laparoscopic hysterectomy. Obstet Gynecol. 2012;119:700–8.
PubMed

Prostatectomy

Bañez LL, Terris MK, Aronson WJ, et al. Race and time from diagnosis to radical prostatectomy: does equal access mean equal timely access to the operating room? Results from the SEARCH database. Cancer Epidemiol Biomarkers Prev. 2009;18:1208–12.
PubMedCentral PubMed

Hayen A, Smith DP, Patel MI, et al. Patterns of surgical care for prostate cancer in NSW, 1993–2002: rural/urban and socio-economic variation. Aust N Z J Public Health. 2008;32:417–20.
PubMed

Hayn MH, Orom H, Shavers VL, et al. Racial/ethnic differences in receipt of pelvic lymph node dissection among men with localized/regional prostate cancer. Cancer. 2011;117:4651–8.
PubMedCentral PubMed

Nambudiri VE, Landrum MB, Lamont EB, et al. Understanding variation in primary prostate cancer treatment within the Veterans Health Administration. Urology. 2012;79:537–45.
PubMed

Oliver SE, Donovan JL, Peters TJ, et al. Recent trends in the use of radical prostatectomy in England: the epidemiology of diffusion. BJU Int. 2003;91:331–6.
PubMed

Trinh QD, Schmitges J, Sun M, et al. Improvement of racial disparities with respect to the utilization of minimally invasive radical prostatectomy in the United States. Cancer. 2012;118:1894–900.
PubMed

Wilt TJ, Shamliyan TA, Taylor BC, et al. Association between hospital and surgeon radical prostatectomy volume and patient outcomes: a systematic review. J Urol. 2008;180:820–8.
PubMed

Knee and Hip Replacement

Ackerman IN, Dieppe PA, March LM, et al. Variation in age and physical status prior to total knee and hip replacement surgery: a comparison of centers in Australia and Europe. Arthritis Rheum. 2009;61:166–73.
PubMed

Bang H, Chiu YL, Memtsoudis SG, et al. Total hip and total knee arthroplasties: trends and disparities revisited. Am J Orthop. 2010;39:E95–102.
PubMed

Centers for Disease Control and Prevention (CDC). Racial disparities in total knee replacement among Medicare enrollees – United States, 2000–2006. MMWR Morb Mortal Wkly Rep. 2009;58:133–8.

Cobos R, Latorre A, Aizpuru F, et al. Variability of indication criteria in knee and hip replacement: an observational study. BMC Musculoskelet Disord. 2010;11:249.
PubMedCentral PubMed

Dixon T, Shaw ME, Dieppe PA. Analysis of regional variation in hip and knee joint replacement rates in England using Hospital Episodes Statistics. Public Health. 2006;120:83–90.

PubMed

Dunlop DD, Manheim LM, Song J, et al. Age and racial/ethnic disparities in arthritis-related hip and knee surgeries. Med Care. 2008;46:200–8.
PubMed

Francis ML, Scaife SL, Zahnd WE, et al. Joint replacement surgeries among medicare beneficiaries in rural compared with urban areas. Arthritis Rheum. 2009;60:3554–62.
PubMed

Hanchate AD, Zhang Y, Felson DT, et al. Exploring the determinants of racial and ethnic disparities in total knee arthroplasty: health insurance, income, and assets. Med Care. 2008;46:481–8.
PubMedCentral PubMed

Hawkins K, Escoto KH, Ozminkowski RJ, et al. Disparities in major joint replacement surgery among adults with Medicare supplement insurance. Popul Health Manag. 2011;14:231–8.
PubMed

Iorio R, Robb WJ, Healy WL, et al. Orthopaedic surgeon workforce and volume assessment for total hip and knee replacement in the United States: preparing for an epidemic. J Bone Joint Surg Am. 2008;90:1598–605.
PubMed

Irgit K, Nelson CL. Defining racial and ethnic disparities in THA and TKA. Clin Orthop Relat Res. 2011;469:1817–23.
PubMedCentral PubMed

Judge A, Welton NJ, Sandhu J, et al. Geographical variation in the provision of elective primary hip and knee replacement: the role of socio-demographic, hospital and distance variables. J Public Health. 2009;31:413–22.

Kurtz SM, Ong KL, Schmier J, et al. Primary and revision arthroplasty surgery caseloads in the United States from 1990 to 2004. J Arthroplasty. 2009;24:195–203.
PubMed

Laudicella M, Siciliani L, Cookson R. Waiting times and socioeconomic status: evidence from England. Soc Sci Med. 2012;74:1331–41.

PubMed

Mäkelä KT, Peltola M, Häkkinen U, et al. Geographical variation in incidence of primary total hip arthroplasty: a population-based analysis of 34,642 replacements. Arch Orthop Trauma Surg. 2010;130:633–9.
PubMed

Ong K, Lau E, Manley M, et al. Patient, hospital, and procedure characteristics influencing total hip and knee arthroplasty procedure duration. J Arthroplasty. 2009;24:925–31.
PubMed

Quintana JM, Escobar A, Arostegui I, et al. Health-related quality of life and appropriateness of knee or hip Joint replacement. Arch Intern Med. 2006;166:220–6.
PubMed

Rahman MM, Kopec JA, Sayre EC, et al. Effect of sociodemographic factors on surgical consultations and hip or knee replacements among patients with osteoarthritis in British Columbia. Canada J Rheumatol. 2011;38:503–9.
PubMed

Skinner J, Weinstein JN, Sporer SM, et al. Racial, ethnic, and geographic disparities in rates of knee arthroplasty among Medicare patients. N Engl J Med. 2003;349:1350–9.
PubMed

Suarez-Almazor ME, Souchek J, Kelly PA, et al. Ethnic variation in knee replacement: patient preferences or uninformed disparity? Arch Intern Med. 2005;165:1117–24.
PubMed

Tomek IM, Sabel AL, Froimson MI, et al. A collaborative of leading health systems finds wide variations in total knee replacement delivery and takes steps to improve value. Health Aff. 2012;31:1329–38.

Cardiac Revascularization

Aguado-Romeo MJ, Márquez-Calderón S, Buzón-Barrera ML, et al. Hospital mortality in acute coronary syndrome: differences related to gender and use of percutaneous coronary procedures. BMC Health Serv Res. 2007;7:110.

PubMedCentral PubMed

Alter DA, Tu JV, Austin PC, Naylor CD. Waiting times, revascularization modality, and outcomes after acute myocardial infarction at hospitals with and without on-site revascularization facilities in Canada. J Am Coll Cardiol. 2003;42(3):410–9.
PubMed

Aragam KG, Moscucci M, Smith DE, et al. Trends and disparities in referral to cardiac rehabilitation after percutaneous coronary intervention. Am Heart J. 2011;161:544–51.
PubMed

Austin D, Oldroyd KG, McConnachie A, et al. Hospital and operator variations in drug-eluting stent use: a multi-level analysis of 5967 consecutive patients in Scotland. J Public Health. 2008;30:186–93.

Bao Y, Kamble S. Geographical distribution of surgical capabilities and disparities in the use of high-volume providers: the case of coronary artery bypass graft. Med Care. 2009;47:794–802.
PubMed

Brown CP, Ross L, Lopez I, et al. Disparities in the receipt of cardiac revascularization procedures between blacks and whites: an analysis of secular trends. Ethn Dis. 2008;18(2 Suppl 2). S2-112-7.

Caillier JG. Race, gender, and cardiovascular disease: do disparities exist at hospitals that serve majority black populations when patients present with ischemic heart disease and myocardial infarction? J Cult Divers. 2006;13:202–7.
PubMed

Coumbe A, John R, Kuskowski M, et al. Variation of mortality after coronary artery bypass surgery in relation to hour, day and month of the procedure. BMC Cardiovasc Disord. 2011;11:63.
PubMedCentral PubMed

Cram P, Bayman L, Popescu I, et al. Racial disparities in revascularization rates among patients with similar insurance coverage. J Natl Med Assoc. 2009;101:1132–9.
PubMed

Gabriel Steg P, Iung B, Feldman LJ, et al. Determinants of use and outcomes of invasive coronary procedures in acute coronary syndromes: results from ENACT. Eur Heart J. 2003;24:613–22.
PubMed

Gaglia Jr MA, Steinberg DH, Pinto Slottow TL, et al. Racial disparities in outcomes following percutaneous coronary intervention with drug-eluting stents. Am J Cardiol. 2009;103:653–8.
PubMed

Gaglia Jr MA, Torguson R, Xue Z, et al. Insurance type influences the use of drug-eluting stents. JACC Cardiovasc Interv. 2010;3:773–9.
PubMed

Grilli R, Guastaroba P, Taroni F. Effect of hospital ownership status and payment structure on the adoption and use of drug-eluting stents for percutaneous coronary interventions. CMAJ. 2007;176:185–90.
PubMedCentral PubMed

Hannan EL, Wu C, Chassin MR. Differences in per capita rates of revascularization and in choice of revascularization procedure for eleven states. BMC Health Serv Res. 2006;6:35.
PubMedCentral PubMed

Hannan EL, Racz M, Walford G, et al. Differences in utilization of drug-eluting stents by race and payer. Am J Cardiol. 2007;100:1192–8.
PubMed

Kamble S, Boyd AS. Health disparities and social determinants of health among African-American women undergoing percutaneous coronary interventions (PCI). J Cult Divers. 2008;15:132–42.
PubMed

Kilbourne BJ, Levine RS, Lambert W, et al. Geographic variations in percutaneous coronary interventions and coronary artery bypass graft surgery among Tennessee elders. South Med J. 2011;104:389–96.
PubMed

Kim DH, Daskalakis C, Lee AN, et al. Racial disparity in the relationship between hospital volume and mortality among patients undergoing coronary artery bypass grafting. Ann Surg. 2008;248:886–92.
PubMed

Korda RJ, Clements MS, Dixon J. Socioeconomic inequalities in the diffusion of health technology: uptake of coronary procedures as an example. Soc Sci Med. 2011;72:224–9.
PubMed

Likosky DS, Goldberg JB, DiScipio AW, et al. Variability in surgeons' perioperative practices may influence the incidence of low-output failure after coronary artery bypass grafting surgery. Circ Cardiovasc Qual Outcomes. 2012;5:638–44.
PubMed

Lin GA, Dudley RA, Redberg RF. Why physicians favor use of percutaneous coronary intervention to medical therapy: a focus group study. J Gen Intern Med. 2008;23:1458–63.
PubMedCentral PubMed

Meyers BM, Vira T, Chow C, et al. Coronary artery bypass graft surgery and primary percutaneous coronary intervention choices in patients with similar coronary anatomy: a computer-based simulation examines the sex gap. Can J Cardiol. 2009;25:649–53.
PubMedCentral PubMed

Movahed MR, Ramaraj R, Jamal MM, et al. Nationwide trends in the utilisation of percutaneous coronary intervention (PCI) in the United States of America based on gender and ethnicities. EuroIntervention. 2009;5:343–8.
PubMed

Mukamel D, Glance L, Weimer D, et al. Racial variations in the choice of on-pump versus off-pump coronary artery bypass grafting. J Health Serv Res Policy. 2007;12:31–5.
PubMedCentral PubMed

Mukherjee D, Wainess RM, Dimick JB, et al. Variation in outcomes after percutaneous coronary intervention in the United States and predictors of periprocedural mortality. Cardiology. 2005;103:143–7.
PubMed

Napan S, Kashinath R, Orig M, et al. Racial difference in cardiovascular outcomes following percutaneous coronary intervention in a public health service patient population. J Invasive Cardiol. 2010;22:168–73.
PubMed

Noguchi H, Shimizutani S, Masuda Y. Regional variations in medical expenditure and hospitalization days for heart attack patients in Japan: evidence from the Tokai Acute Myocardial Study (TAMIS). Int J Health Care Finance Econ. 2008;8:123–44.
PubMed

Quin JA, Sheng S, O'Brien SM, et al. Regional variation in patient risk factors and mortality after coronary artery bypass grafting. Ann Thorac Surg. 2011;92:1277–82.
PubMed

Riley RF, Don CW, Powell W, et al. Trends in coronary revascularization in the United States from 2001 to 2009: recent declines in percutaneous coronary intervention volumes. Circ Cardiovasc Qual Outcomes. 2011;4:193–7.
PubMedCentral PubMed

Saleh SS, Hannan EL, Ting L. A multistate comparison of patient characteristics, outcomes, and treatment practices in acute myocardial infarction. Am J Cardiol. 2005;96:1190–6.
PubMed

Thompson CA, Kaplan AV, Friedman BJ, et al. Gender-based differences of percutaneous coronary intervention in the drug-eluting stent era. Catheter Cardiovasc Interv. 2006;67:25–31.
PubMed

Tu JV, Ko DT, Guo H, et al. Determinants of variations in coronary revascularization practices. CMAJ. 2012;184:179–86.
PubMedCentral PubMed

West RM, Cattle BA, Bouyssie M, et al. Impact of hospital proportion and volume on primary percutaneous coronary intervention performance in England and Wales. Eur Heart J. 2011;32:706–11.
PubMed