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“Big data” in health care Assessment of the performance of Greek NHS hospitals using key performance and clinical workload indicators

OBJECTIVE To examine how common key performance indicators (KPIs) change when clinical workload indicators of hospitals, based on diagnosis-related group (DRG) data, are incorporated in the measurement analysis. From the data and knowledge management perspective the available data fulfill all four “V” challenges (volume, velocity, variety, veracity) and the “D” challenge (distribution of data sources) that characterize the “big data” era. **METHOD** Analysis was made of the annual detailed financial, operational and patient data as recorded by the ESY.net web application, for 129 Greek National Health System (NHS) hospitals. Four KPIs were calculated based on the hospital financial and patient data. The indicators were then adjusted to the case mix (i.e., clinical workload) of the units, using a hospital clinical weight (HCW) indicator based on the DRG data. **RESULTS** Significant changes in the KPIs resulted from adjustment according to DRG, in both percentages and the relative ranking of hospitals as efficient and inefficient. After adjustment, improvement in indicators and relative ranking was observed for hospitals with more severe than average incidents, such as cancer hospitals, cardiac surgery centers, etc., but also for some general hospitals and health centers, while other small health centers and regional hospitals ranked lower after adjustment. **CONCLUSIONS** The significant changes in the performance ranking of hospitals observed after adjustment of the KPIs according to the clinical workload of the units, render this tool inappropriate for use by decision makers in the health care sector, i.e., the Ministry of Health (MoH), as they provide misleading information when the diversity in the HCW is not taken into account. The results of the study support the need for re-evaluation of the assessment methodology of Greek NHS hospitals, in order to identify the weaknesses in the system, improve its efficiency and achieve improvement.

Greece is suffering from a financial crisis of unprecedented intensity, the impact of which on the health care sector is prominent. Continuous efforts by the government to reduce public spending have unsurprisingly led to reductions in health care funding and thus in hospital budgets. Optimal utilization of the limited health care resources is therefore imperative. The measurement of hospital performance has become a primary objective for the Ministry of Health (MoH) in its attempts to identify weaknesses and to reform the Greek National Health System (NHS).

Measurement of hospital performance in the Greek NHS has not yet reached a satisfactory level, as reliable and well-documented research in this area is limited. A

common omission in the estimation of the performance indicators that have been used is that the diverse nature of the case mix of the hospitals is not taken into account, resulting in misleading results and faulty recommendations to the policy makers.

Computerization of the Greek NHS hospitals is now at an adequate level, with systematic, real time recording and monitoring of operational and financial indicators, through hospital information systems (ESY.net) providing key performance indicators (KPIs). In addition, the introduction of diagnosis-related groups (DRGs), which can quantitatively describe the case mix of hospitals, provides the possibility of adjusting the performance indicators taking into account the hospital clinical workload (HCW).

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ΑΡΧΕΙΑ ΕΛΛΗΝΙΚΗΣ ΙΑΤΡΙΚΗΣ 2016, 33(4):489–497

A. Christodoulakis,¹
H. Karanikas,²
A. Billiris,¹
E. Thireos,³
N. Pelekis⁴

¹Datamed SA, Athens

²National and Kapodistrian University
of Athens, Athens

³Athens Medical Society, Athens

⁴Department of Statistics and Insurance
Science, University of Pireus, Pireus,
Greece

«Μεγάλα δεδομένα υγείας»:
Αξιολόγηση απόδοσης
νοσοκομείων του Εθνικού
Συστήματος Υγείας με τη χρήση
KPIs και δεικτών κλινικού έργου

Περίληψη στο τέλος του άρθρου

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From the perspective of data and knowledge management it is argued that the available data fulfills all four “V” challenges (volume, velocity, variety, veracity) and the “D” challenge (distribution of data sources) that characterize the “big data” era.^{1,2}

In medical informatics, which can be considered one of the pillars of the big data era, the recent inception of large scale database technologies, patient monitoring and sensor technologies results in huge amounts of medical data being generated by hospitals and medical organizations at unprecedented speed. These data are of a heterogeneous nature, and the daily rate of appending new data is rapidly increasing. These data provide a valuable resource for use in improving health, health care delivery and medical decision-making. The unique characteristics of contemporary medical data call for new data management and analysis techniques that are based on a scalable processing model¹ and can identify interesting patterns or hidden knowledge effectively.²

The aim of this study was to calculate performance indicators for the Greek NHS hospitals, adjusted according to their clinical workload using the DRG data, thus providing corrections to the current assessment of hospital performance and allowing comparison between the various different types of hospitals. The study also examined whether and to what degree the initial indicators are affected by the introduction of the DRG data. Interpretation of the findings provided useful feedback for policy makers regarding evaluation of Greek NHS hospitals and identified potential weaknesses that undermine the system’s performance.

The current study is the first to estimate KPIs for Greek NHS hospitals adjusted according to their clinical workload, thus allowing comparison between hospitals of different types. In this process of adjusting the KPIs, unique clinical weight indicators were assigned to each hospital representing the severity of the incidents dealt with by the hospital as a single number, which is innovative for the Greek NHS.

MATERIAL AND METHOD

The data used for this study were the annual detailed financial and operational data for the year 2013, as recorded by the web application ESY.net, which are available in processable form on the website of the MoH at the hospital, Health Care Region (HCR) and nationwide levels.^{3,4}

Financial indicators and hospital activity data

The financial indicators include annual expenditure for raw and auxiliary materials (pharmaceuticals, hygiene supplies, or-

thopedic equipment, reagents, etc.), consumables (gas, fuel, etc.) and detailed data on salaries, payments and revenues for every hospital, health center, HCR and the entire NHS.⁴

The hospital activity data include the number of inpatients and the total hospitalization days, the number of outpatients and the emergency services for every hospital and health center, HCR and the entire NHS.³

Diagnosis-related group data

In cooperation with the company that manages the information systems of the hospitals, primary DRG data were collected directly from hospital databases. These data include the incidence of each DRG for each hospital, its name and code, its associated indicative and actual duration of hospitalization, its indicative and actual cost and, and its cost weight.

Categorization of hospitals

To ensure comparability with previous studies, the 129 hospitals in the study were divided into four categories based on their size (number of beds) as follows: <100 beds (35 hospitals), 101–250 beds (44 hospitals), 251–400 beds (21 hospitals), >400 beds (29 hospitals).

It should be noted that in contrast with previous studies, the hospitals were not grouped by type, as their workload was subsequently adjusted using the DRG data.

Key performance indicators

In order to evaluate the performance of the health care units, a set of appropriate KPIs was adopted. Such indicators are widely used for the identification of gaps in the quality or efficiency of the services provided.

This study estimated and examined the following KPIs: *mean cost per patient*, defined as the total expenditure (expenditure for raw and auxiliary materials and consumables etc., excluding payroll) of a hospital, divided by the number of hospitalized patients, for 2013; *mean cost per hospital day*, defined as the total expenditure (expenditure for raw and auxiliary materials and consumables etc., excluding payroll*) of a hospital, divided by the total number of hospital days, for 2013; *mean drug cost per patient*, defined as the total pharmaceutical expenditure of the hospital, divided by the number of hospitalized patients, for 2013; *mean laboratory cost per patient*, defined as the hospital’s total expenditure for reagents, divided by the number of hospitalized patients, for 2013.

Diagnosis-related group-based adjustment of key performance indicators

In order to adjust the indicators according to the workload

* As reported in the second section, the hospital payroll is covered by subsidies from the Ministry of Health (MoH) and is completely separate from the hospital’s global budget. Due to this special condition, the payroll is excluded from the measurement of the indicators.

of the hospitals, for each health care unit a single indicator, the hospital clinical weight (HCW, representing the clinical weight of all incidents dealt with by the hospital in 2013) was calculated, as follows:

$$HCW_i = \frac{\sum_{\text{for all DRGs}} (f_{i,DRG} * weight_{DRG})}{\sum_{\text{for all DRGs}} (f_{i,DRG})}, \text{ for all hospitals } i \quad (3.3.1)$$

where $f_{i,DRG}$ is the number of occurrences (i.e. frequency) of a specific DRG for hospital i and $weight_{DRG}$ is the relative cost weight for that DRG.

Indicatively, the above procedure is presented in the Appendix, for the “KAT” General Hospital of Attica. The estimated HCW indicators for the 7 HCRs and for the entire NHS are shown in the Appendix (tab. 1).

The adjustment of the KPIs to the clinical workload of hospitals results from division of the initial indicators by the HCW, namely:

$$adjusted\ KPI_i = KPI_i / HWC_i = KPI_i / HWC_b, \text{ for each hospital } i$$

In order to evaluate the effect of the severity of incidents (case mix) on the KPIs, the percentage change of indicators after adjustment was calculated. In addition, the ranking of the hospitals, with respect to a particular indicator for each category, was considered before and after the adjustment.

Limitations of the study

The main limitation of the current study is that when estimating the KPIs, potential differences in clinical outcome (clinical effectiveness) across hospitals were not taken into account, as it was assumed that incidents that belong to the same diagnostic category have the same outcomes. This assumption can be considered valid, as the classification of incidents in DRGs integrates to a significant extent similar cases, so long as outlier cases, the cost of which differs significantly from the average of the category, are taken into account. In addition, the assumption was based on the treatment of a specific incident being consistent with the medical protocols of the MoH, to which the providers adhere, although this does not correspond to the common Greek practice, where protocols may have only an indicative role.

Table 1. Number of beds, patients, hospital days and hospital clinical weight values for the 7 Health Care Regions (HCR) and in the National Health System (NHS) in total.

Health care region	Number of beds	Number of patients	Hospital days	Hospital clinical weight
HCR 1	8,982	630,889	2,438,569	1.233
HCR 2	6,223	307,761	1,757,046	1.297
HCR 3	4,064	265,890	1,040,872	0.917
HCR 4	4,693	341,405	1,054,407	0.846
HCR 5	2,510	206,464	617,899	0.732
HCR 6	5,344	370,709	1,328,560	0.884
HCR 7	2,275	150,633	544,881	0.995
Total	34,092	2,273,751	8,782,234	1.029

A further limitation of the study is the fact that other dimensions of hospital performance, as defined by World Health Organization (WHO),⁶ were not taken into account. For example, patient centeredness, client orientation (i.e., access, information and empowerment, continuity) and appropriateness of services were not considered in the evaluation of the health units.

RESULTS

The performance indicators were first calculated for the 4 hospital categories according to their size (number of beds), without taking into account the severity of the incidents, and then adjusted, using the HCW indicators. The most important findings of the study are presented here.

Hospital efficiency based on key performance indicators

In order to ensure comparability with the earlier reports of the MoH,⁵ the 10 “best” hospitals of each category are presented graphically, along with the aggregated results for the 7 HCRs and the entire NHS, based on each of the indicators examined, after adjustment according to the HCW indicators.

The 10 hospitals with the lowest mean cost per patient, the lowest mean cost per hospital day, the lowest mean drug cost per patient and the lowest mean laboratory cost per patient, for the 4 size categories, for 2013, after adjustment according to the HCW indicators, are illustrated in figures 1 to 4, respectively.

After adjustment, it is evident that changes in both ranking of hospitals, and the percentage change of the indicators are significant. In addition, considerable differences can be observed from comparison with the results of the MoH ranking the “best” hospitals.⁵ In the next section, several specific cases of hospitals and health centers with remarkable changes in indicators or ranking on adjustment are presented and analyzed.

How key performance indicators are affected by adjustment for hospital clinical weight

This section shows the effect on the performance indicators of the severity of cases (i.e., the differences in case mix) that a hospital deals with. The goal is to assess whether such indicators, which are considered a basic criterion of evaluation of hospital performance, can provide reliable results for the MoH.

Figure 5 presents the mean cost per patient, before and after adjustment according to HCW, and its percentage

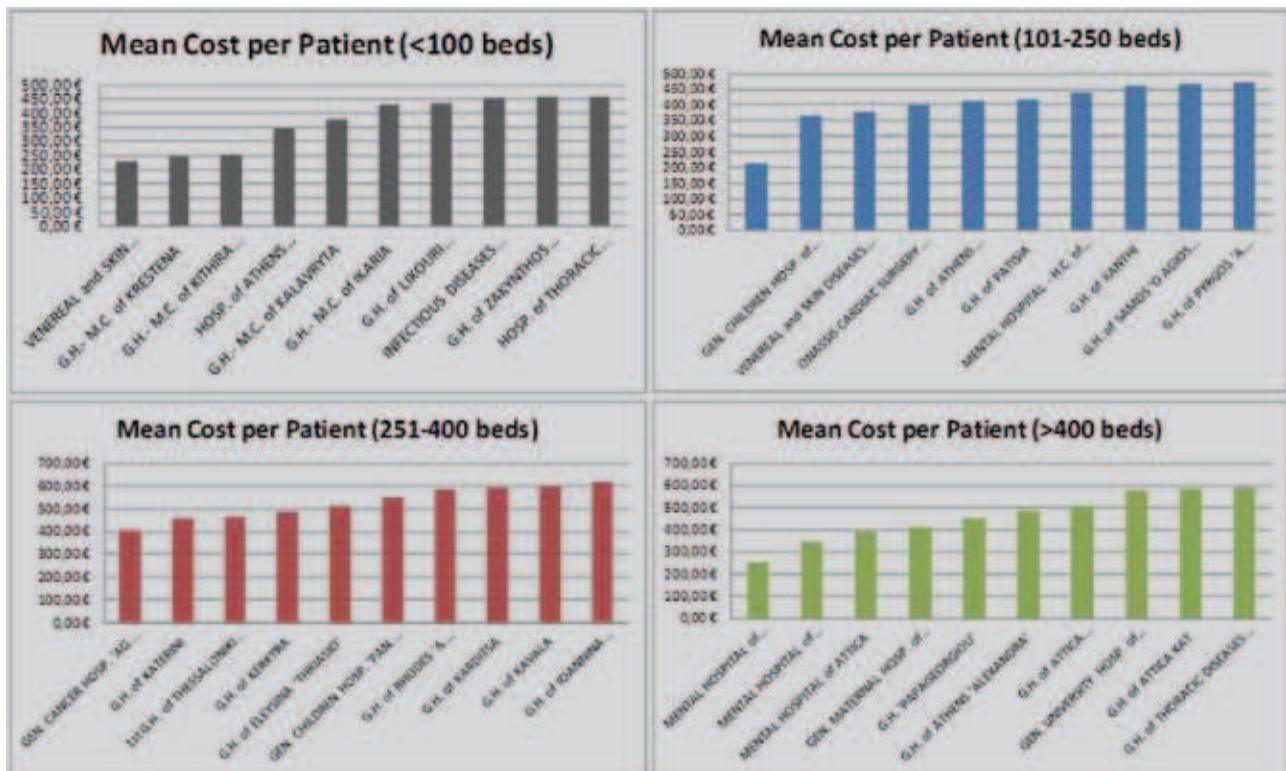


Figure 1. The 10 hospitals with the lowest cost per patient (<100, 100–250, 251–400, >400 beds).

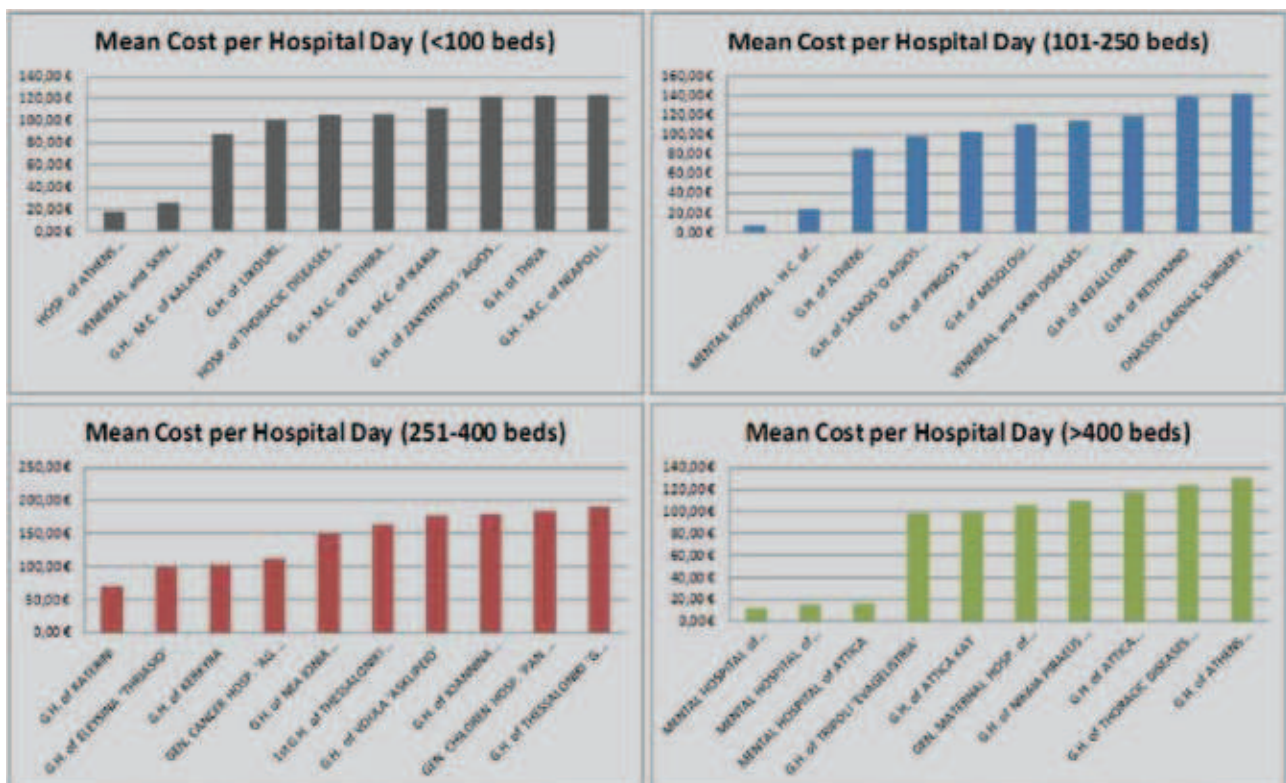


Figure 2. The 10 hospitals with the lowest cost per hospital day (<100, 100–250, 251–400, >400 beds).

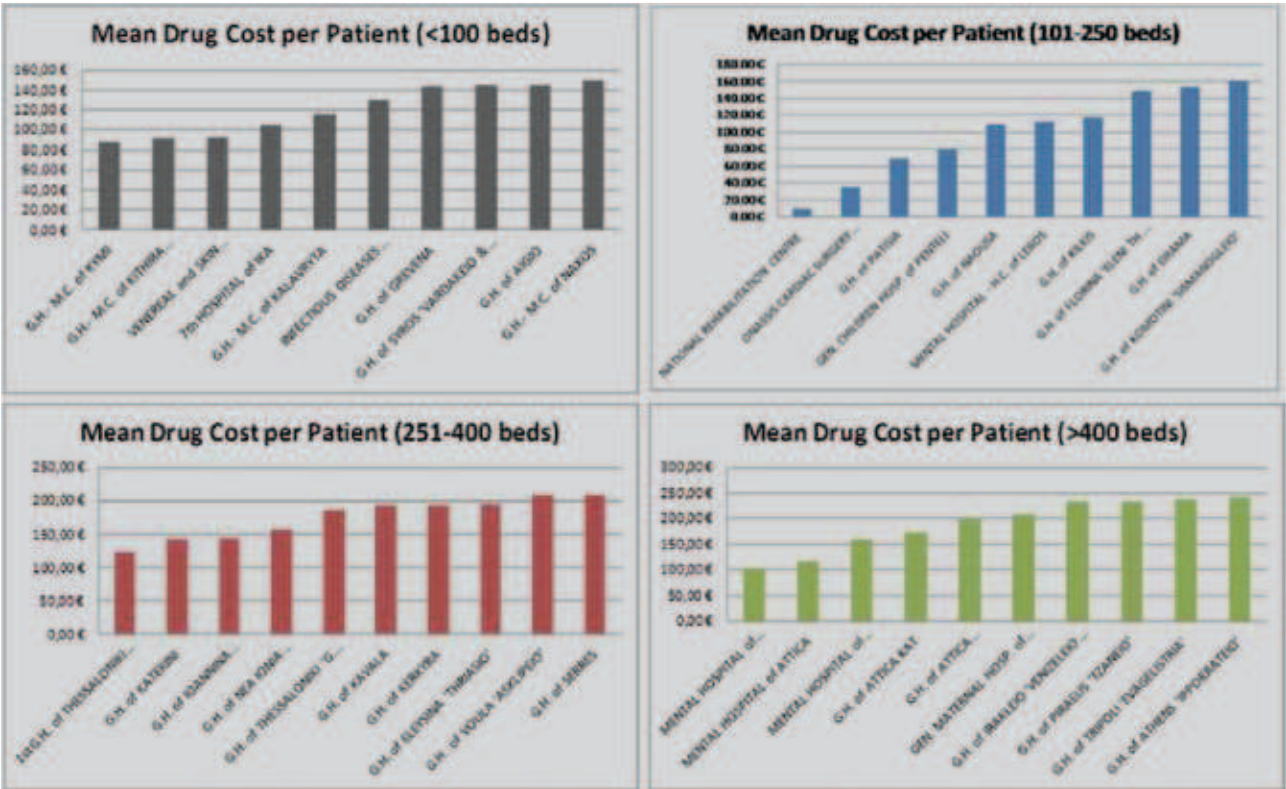


Figure 3. The 10 hospitals with the lowest drug cost per patient (<100, 100–250, 251–400, >400 beds).

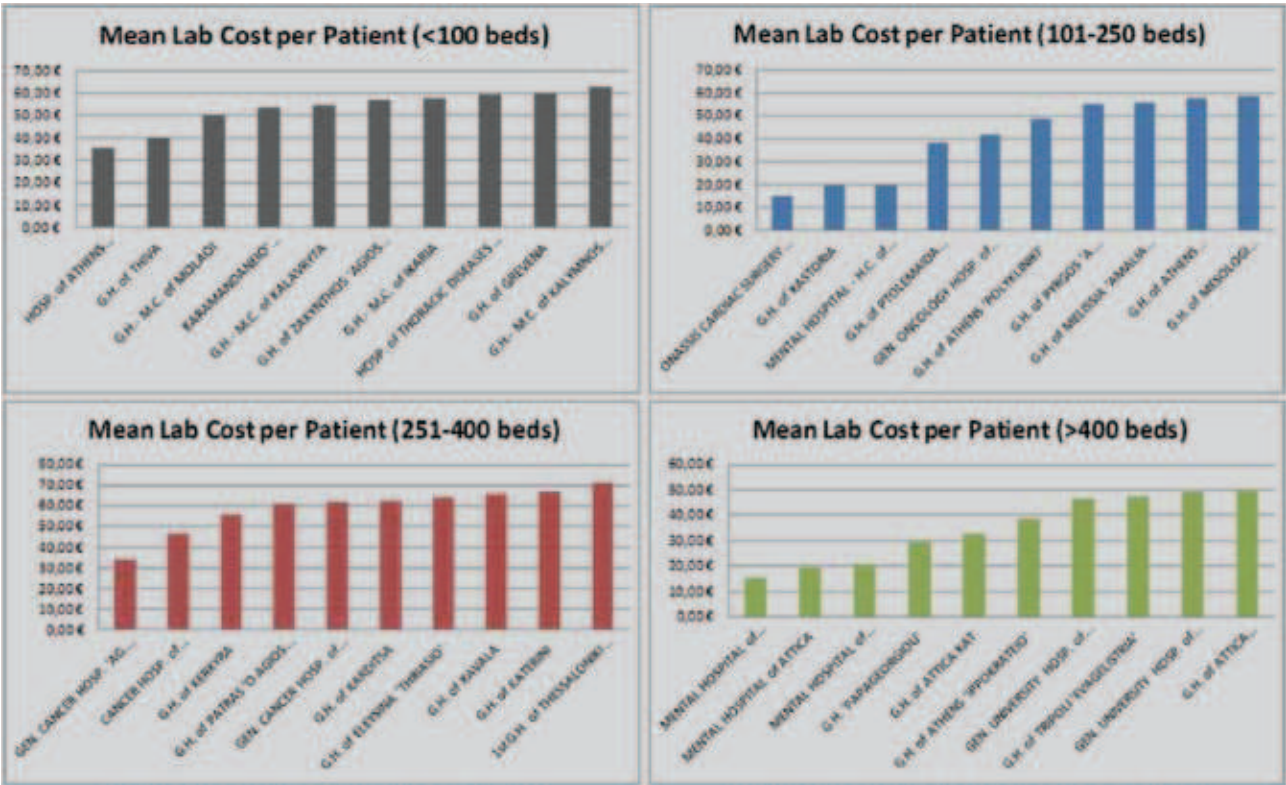


Figure 4. The 10 hospitals with the lowest laboratory cost per patient (<100, 100–250, 251–400, >400 beds).

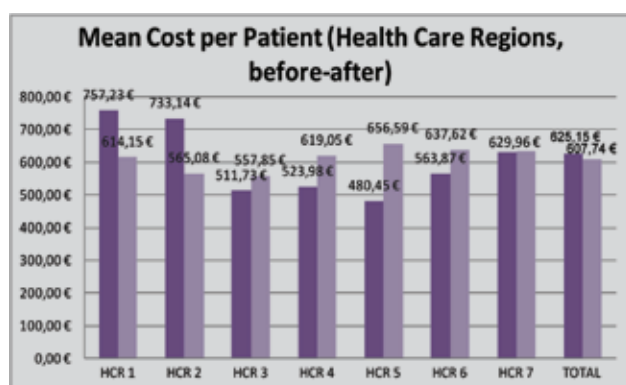


Figure 5. Mean cost per patient for the 7 Health Care Regions (HCR) and the National Health System in total, before and after adjustment (before-after).

change, for the 7 HCRs and the NHS in total. The percentage change after adjustment is the same for the other indicators, as they were divided by the same number, namely the HCW of each hospital.

As can be seen, the change in the indicators after adjustment was significant for most regions, ranging from a 36.66% increase for the 5th HCR, to a 22.92% decline for the 2nd HCR. For the NHS as a whole, there was a slight decrease of 2.79%, which was expected, as the cost weight trends towards 1 (average case), as the sample size increases. Although small, the fact that there is a change of indicators for the NHS in total can be interpreted as a nationwide reduction in the severity of cases overall, which is consistent with the Ministry's report,⁵ suggesting that in 2013 there was a reduction in patient visits.

At this point, we present some specific cases of hospitals and health centers that showed a remarkable change in indicators, either in percentage or in a change of ranking after adjustment for HCW. It should be noted that in the present study the hospitals were not divided according to their type, thus allowing greater fluctuations in their rankings.

Figure 6 shows the mean cost per patient for selected hospitals with less than 100 beds. In this category, an interesting case is that of the Krestena General Hospital-Health Center (GH-HC), which had a mean cost per patient of 807.80 €, before adjustment of the indicators, and was in the 34th place, with the second highest cost per patient, while after adjustment the cost was 248.39 € per patient, a reduction of 69.25%, the second lowest in its category. This is justified because the HCW of this hospital was 3.252, i.e., it recorded incidents more than three times costlier than the average. A similar case is that of the Athens Spiliopouleio Hospital "Aghia Eleni", with a cost per patient of 788.92 € before adjustment, the third highest, and 347.88 € after

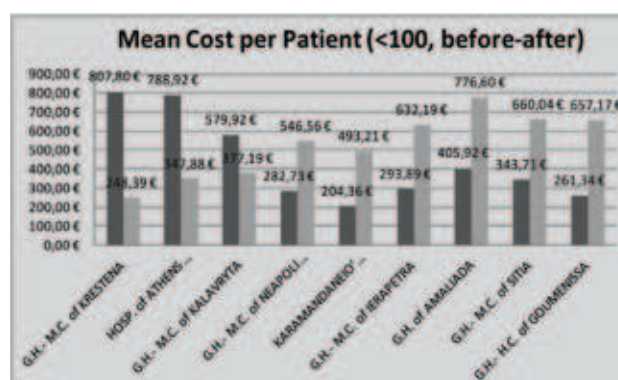


Figure 6. Cost per patient for selected hospitals with less than 100 beds before and after adjustment (before-after).

the adjustment, the fourth lowest, showing a decrease of 55.9%. On the other hand, the Goumenissa GH-HC had a mean cost per patient of 261.34 € before adjustment, the 6th lowest in its category, and 657.17 € after adjustment, becoming the 6th highest, showing an increase of 151.46%.

As estimated following adjustment for HCW, only 4 of the 10 hospitals with the lowest cost per patient before adjustment remained in the top 10 after adjustment.

The results for the mean cost per hospital day, the mean drug cost per patient and the mean laboratory cost per patient show similar changes to those described above for the mean cost per patient, in all the unit size categories examined.

DISCUSSION

The analysis of the "big data" in the health care sector in this study, with adjustment of the indicators according to the clinical workload of the hospitals and the severity of the incidents they treat, are of particular importance. As reported above, the change in the indicators and the ranking of the hospitals, with differentiation of the more and less efficient hospitals, were highly significant for all categories of health care unit and all indicators.

This change is directly related to the case mix of hospitals, which is indicated by the estimated HCW. The HCW reflects how many resources are required by a hospital, based on the incidents it deals with. As expected, these indicators were very high for cardiac surgery and cancer hospitals, hospitals for venereal and skin diseases and accident rehabilitation centers, as by definition such hospitals are specialized in treating severe cases. The effect of the adjustment, therefore, was a significant improvement (decrease) in the KPIs for these hospitals. Conversely, the

HCWs were mainly lower for the smaller health centers and regional hospitals, as the severe incidents of these hospitals are typically forwarded to the nearest larger urban hospital. Adjustment thus resulted in an increase in KPIs for these hospitals and a drop in their ranking.

At this point, it is of note that the findings of the study verify the poorer performance of several health center and smaller regional hospital, compared with the initial estimates, in contrast to the improved performance of larger hospitals in Athens and other large cities, after adjustment of the indicators according to DRG data.⁷ This phenomenon had not been previously detected by the studies and reports of the MoH,⁵ with significant negative implications for the performance of the current MoH assessment system. One possible interpretation is that economies of scale are in operation, which increase the efficiency of health units dealing with incidents that occur more frequently. In other words, an unusual incident, challenging in resources, is more costly when treated in a small health center than in a large hospital with experience in dealing with similar incidents.

In addition, the fact that for this study the hospitals were not separated by type, but only in terms of their size, measured by their number of beds, played an important role in the significant change in their ranking. This does not mean, however, that there were no significant changes in indicators and rankings in general hospitals and health centers. Many hospitals with a high severity of incidents, which were excluded from previous studies, were apparently at the bottom of the rankings in their categories before adjusting the indicators, but showed a considerable improvement when the indicators were adjusted according to the clinical workload.

Another example of the incorporation of the HCW is that before adjusting the results, the lowest cost per patient was 145.28 € in the Thessaloniki Mental Diseases Hospital and the highest was 2,488.15 € in "Onassis" Cardiac Surgery Center. The sample average was 548.11 €, with a standard deviation (SD) of 285.06 €. After adjustment of the indicators according to HCW, the lowest cost per patient was 213.77 € for the National Rehabilitation Center, and the highest 1,502.4 € for the 7th Hospital of IKA (Social Security Foundation). The sample average was 579.72 €, with SD 139.58 €, greatly reduced from the SD before adjustment. The results for the other indicators were similar, with the SD being reduced significantly on adjustment in all categories.

A possible interpretation is that a considerable part of the apparent differences in the performance of the various hospitals was due to the differences in their case mix.

Policy implications

These findings have important implications for the policy makers. It is evident that the earlier results of the MoH, which were based solely on financial and patient activity data, are unreliable. They do not provide useful and accurate information about real hospital performance, nor the possibility of identifying potential weaknesses of the system or achieving the desired improvement in efficiency.^{7,8} It can be concluded that the estimation of KPIs alone is not an appropriate tool on which to base decision-making for the health sector, as it provides misleading information.

Hence, in the wider environment of economic crisis, where the reduction of funding for health care requires the optimal utilization of scarce resources for the benefit of patients, the attention of policy makers should be refocused in the right direction. In other words, corrective and structural changes need to be made in the organization of those hospitals that present inefficiencies, but only after taking into account the severity of the incidents that these hospitals deal with, so that interventions are targeted at the real problems. This means that efforts should be made to improve the performance of the remote regional health centers and small hospitals, appear on the adjusted data to have the worst performance.

It is appropriate to reassess the medical, nursing and administrative personnel of the small hospitals through an evaluation process, in order to optimally utilize the present human resources and if necessary provide additional specialized, high-level personnel. A possible re-evaluation of the services provided by small health centers would be useful, to ensure that they do not provide inefficient services because of their small scale. Certain services can be provided more efficiently by larger urban hospitals due to the greater number of incidents they deal with, without undermining the quality of services provided or affecting patient safety. Finally, possible mergers of certain hospitals and or health centers could possibly improve some of the inefficiencies of the system. The primary concern when planning such changes should be to ensure first the optimal population coverage and then improvement in efficiency.

ΠΕΡΙΛΗΨΗ

«Μεγάλα δεδομένα υγείας»: Αξιολόγηση απόδοσης νοσοκομείων του Εθνικού Συστήματος Υγείας με τη χρήση KPIs και δεικτών κλινικού έργου

Α. ΧΡΙΣΤΟΔΟΥΛΑΚΗΣ,¹ Χ. ΚΑΡΑΝΙΚΑΣ,² Α. ΜΠΙΛΛΗΡΗΣ,¹ Ε. ΘΗΡΑΙΟΣ,³ Ν. ΠΕΛΕΚΗΣ⁴

¹Datamed ΑΕ, Αθήνα, ²Εθνικό και Καποδιστριακό Πανεπιστήμιο Αθηνών, Αθήνα, ³Ιατρική Εταιρεία Αθηνών, Αθήνα,

⁴Πανεπιστήμιο Πειραιά, Πειραιάς

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ΣΚΟΠΟΣ Στην παρούσα μελέτη διερευνήθηκε κατά πόσο οι βασικοί δείκτες απόδοσης (KPIs) των νοσοκομείων του Εθνικού Συστήματος Υγείας (ΕΣΥ) μεταβάλλονται, όταν γίνεται προσαρμογή στο κλινικό τους έργο, κάνοντας χρήση δεδομένων κλειστών ενοποιημένων νοσηλείων (ΚΕΝ). Τα παρόντα δεδομένα ικανοποιούν τις τέσσερις “V” προκλήσεις: Volume (όγκος), velocity (ταχύτητα), variety (ποικιλία) και veracity (βεβαιότητα ή ακριβή στοιχεία), καθώς και την πρόκληση “D”: distribution of data sources (κατανομή των πηγών δεδομένων), που αποτελούν την εποχή «μεγάλων δεδομένων». **ΥΛΙΚΟ-ΜΕΘΟΔΟΣ** Τα δεδομένα που χρησιμοποιήθηκαν περιλάμβαναν ετήσια οικονομικά και λειτουργικά στοιχεία των νοσοκομείων, όπως αυτά καταγράφονταν στη διαδικτυακή εφαρμογή ESY.net, για 129 νοσοκομεία του ΕΣΥ. Στη μελέτη υπολογίστηκαν τέσσερις βασικοί δείκτες απόδοσης. Για κάθε νοσοκομείο υπολογίστηκε ένας δείκτης βαρύτητας περιστατικών, ως ο σταθμισμένος μέσος των ΚΕΝ που καταγράφηκαν για το 2013, με βάση τη σχετική βαρύτητα των επί μέρους περιστατικών. Με χρήση του συγκεκριμένου δείκτη εφαρμόστηκε η προσαρμογή των KPIs στο κλινικό έργο των μονάδων. **ΑΠΟΤΕΛΕΣΜΑΤΑ** Τα ευρήματα της μελέτης κατέδειξαν σημαντικές μεταβολές, τόσο σε ποσοστό, όσο και στη σχετική κατάταξη των νοσοκομείων ως προς την απόδοσή τους. Οι σημαντικότερες μεταβολές παρουσιάστηκαν στα αντικαρκινικά νοσοκομεία και στα καρδιοχειρουργικά κέντρα, αλλά και σε ορισμένα γενικά νοσοκομεία και κέντρα υγείας, που βελτίωσαν τους δείκτες τους. Αντίθετα, μικρά και απομακρυσμένα κέντρα υγείας, αλλά και νοσοκομεία στην περιφέρεια, παρουσίασαν χειρότερα αποτελέσματα μετά την προσαρμογή των δεικτών. **ΣΥΜΠΕΡΑΣΜΑΤΑ** Από τη μελέτη συμπεραίνεται ότι οι σημαντικές μεταβολές στη σχετική κατάταξη των μονάδων υγείας, που επήλθαν ύστερα από προσαρμογή των δεικτών τους στο κλινικό έργο, καθιστά τη χρήση των βασικών δεικτών απόδοσης ακατάλληλη για τη λήψη αποφάσεων στον χώρο της υγείας (Υπουργείο Υγείας), στην περίπτωση κατά την οποία η διαφορετικότητα του κλινικού έργου δεν λαμβάνεται υπ’ όψη. Τα αποτελέσματα της μελέτης ενισχύουν την ανάγκη για επαναξιολόγηση της απόδοσης των νοσοκομείων του ΕΣΥ, προκειμένου να εντοπιστούν αδυναμίες του συστήματος και να βελτιωθεί η αποδοτικότητά του.

Λέξεις ευρητηρίου: Απόδοση νοσοκομείων, Δείκτες απόδοσης, Κλινικός δείκτης απόδοσης, Μεγάλα δεδομένα Υγείας

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Corresponding author:

A. Christodoulakis, 71 Kifissias Ave. & Grammou street, GR-151 24 Marousi, Greece
e-mail: alex@datamed.gr

APPENDIX

An example of calculating hospital clinical weight

At this point, the calculation procedure of the HCW, using indicatively the “KAT” General Hospital of Attika, is presented. Detailed data of the incidents recorded for year 2013 were collected from the hospital database. Specifically, the occurrence of each DRG and the cost weight assigned to it are shown in table 2.

Equation (3.3.1) was applied to the data, as follows:

$$HCW_i = \frac{\sum_{for\ all\ DRGs} (f_{i,DRG} * weight_{DRG})}{\sum_{for\ all\ DRGs} (f_{i,DRG})} = \frac{656*0.240 + 611*4.423 + 576*0.589 + \dots + 88*1.041 + 82*1.596 + 82*1.494}{656 + 611 + 576 + \dots + 88 + 82 + 82} = \frac{11,400.129}{7,247} = 1.552$$

The above procedure was applied to all hospitals in the study.

Table 2. Diagnosis-related group (DRG) frequency and cost weights for the “KAT” General Hospital of Attika, for the year 2013.

DRG coding	Frequencies of DRGs	DRG cost weight
Δ27X	656	0.240
M08X	611	4.423
M71X	576	0.589
N05A	540	0.400
M22A	398	2.399
M68A	356	0.242
M03X	273	4.799
M74A	271	0.560
Π46A	261	0.523
X24X	260	0.283
M04X	244	6.398
M75X	242	0.589
M30A	233	1.131
M23A	214	0.560
M66M	195	3.542
Π10X	186	1.388
K46X	182	0.710
K44A	168	0.496
M66X	158	0.656
M68X	155	1.169
M28M	133	3.837
M69X	129	0.680
M27X	126	1.312
M13M	118	1.740
M20A	114	1.723
K20A	103	1.105
M76X	101	0.622
K37X	92	0.568
Φ25X	88	1.041
M19X	82	1.596
Φ24X	82	1.494