EFFICIENCY OF HEALTH AND SOCIAL CARE PROVISION AT UNIVERSITY HOSPITALS

Samuel Cavalcante Mota [1]
Antonio Rafael Valério de Oliveira [2]
Alessandra Carvalho de Vasconcelos [3]

▪ Received: 07/15/2021 ▪▪ Approved: 09/07/2021 ▪▪▪ Second Approved Version: 10/29/2021

ABSTRACT

Developing countries have been strongly impacted by the worldwide rise in healthcare costs due to population aging, inflated medical costs, and economic and social polarization. Thus, public administrators, especially in the health sector, face the challenge of improving resource efficiency. At university hospitals, resource-efficient health and social care provision are further encumbered by research and teaching demands. Starting in 2011, the EBSERH (a Brazilian hospital management contractor) took over the management of a string of public hospitals, emphasizing efficiency. This study evaluated the efficiency of health and social care provision at 40 federal university hospitals managed by the EBSERH. Variables collected for 2018 were submitted to data envelopment analysis, output-oriented Banker-Charnes-Cooper modeling, and testing and correlation of means. Efficiency was confirmed for ten hospitals, six of which were located in Northeastern Brazil. The five least efficient hospitals included two facilities in Rio de Janeiro. Mortality was the variable with the most significant potential for improvement, suggesting managers give more attention to this issue. Hospital size was significantly associated with efficiency, but no significant correlation was found between efficiency and the percentage of expenses covered by the hospital's revenues vs. the Universal Health Care System (SUS).

Keywords: Efficiency, Health and social care, University hospitals.

[1] Mestre em Administração e Controladoria pela Universidade Federal do Ceará (UFC), Contador da Universidade Federal do Ceará (UFC). Endereço: Av. da Universidade, 2853, Coordenadoria de Contabilidade e Finanças, Pró-Reitoria de Planejamento e Administração, Bairro Benfica, Fortaleza/CE, Brasil, CEP: 60020-181. Telefone: (85) 3366-7934. E-mail: samuelcmota@hotmail.com.
https://orcid.org/0000-0001-9197-1467

[2] Mestre em Administração e Controladoria pela Universidade Federal do Ceará (UFC), Contador da Universidade Federal do Cariri (UFCA). Endereço: Av. Tenente Raimundo Rocha, 1639, Bloco I, Sala 405, Auditoria Interna, Bairro Cidade Universitária, Juazeiro do Norte/CE, Brasil, CEP: 63048-080. Telefone: (88) 3221-9490. E-mail: rafaelvalerio65@gmail.com.
https://orcid.org/0000-0001-9970-4953

[3] Doutora em Engenharia de Produção pela Universidade Federal de Santa Catarina (UFSC). Docente do Programa de Pós-Graduação em Administração e Controladoria da Universidade Federal do Ceará (UFC). Endereço: Av. da Universidade, 2431, Bairro Benfica, Fortaleza/CE, Brasil, CEP: 60020-180. Telefone: (85) 3366-7802. E-mail: alevasconcelos.ufc@gmail.com.
https://orcid.org/0000-0002-6480-5620

EFICIÊNCIA DO ATENDIMENTO ASSISTENCIAL NOS HOSPITAIS UNIVERSITÁRIOS

RESUMO

O aumento dos gastos com saúde, afeta mais os países em desenvolvimento, sobretudo em função do envelhecimento populacional, da inflação dos custos médicos e da polarização econômica e social. Um dos maiores desafios para o gestor público, em especial de saúde, consiste em buscar ganhos de eficiência, já que os recursos são escassos. Referente aos hospitais universitários, a complexidade do atendimento assistencial é agravada pelo acréscimo das atividades de ensino e pesquisa. A criação da Empresa Brasileira de Serviços Hospitalares (EBSERH) em 2011 implementou a gestão empresarial, onde se acentua a pressão por eficiência. Nesse contexto, o estudo avalia a eficiência do atendimento assistencial nos hospitais universitários federais geridos pela EBSERH. Foi procedida a Análise por Envoltória de Dados (DEA), Modelo BCC (Banker-Charnes-Cooper), com orientação para outputs, para o cálculo da eficiência dos 40 hospitais que mantêm contrato com a EBSERH. Foram aplicados correlação e testes de médias sobre os dados de 2018. Os resultados indicam que 10 hospitais são eficientes, sendo seis localizados na Região Nordeste. Dentre os cinco hospitais com os mais baixos níveis de eficiência, incluem-se os dois do Rio de Janeiro. A taxa de mortalidade foi a variável que apresentou o maior potencial de melhoria, requerendo mais atenção dos gestores. Não foi identificada correlação significante entre a eficiência nos hospitais e a porcentagem de despesas custeadas por fontes de receitas próprias e do SUS. Além disso, observou-se uma diferença entre o nível de eficiência nos hospitais universitários de maior porte e o daqueles de menor porte.

Palavras-Chave: Eficiência, Atendimento assistencial, Hospitais universitários.

1 INTRODUCTION

The amount spent on healthcare and its results in terms of quality and efficiency constitute issues of great relevance either in the private segment or in the Public Administration, given the magnitude of expenses in the sector. According to a recent World Health Organization (WHO) report, accounting for public and private expenditure, the global health spending already represents 10% of Gross Domestic Product (GDP) worldwide. The increasing number of expenses is faster in low- and medium-income countries where health expenditures grow by 6% on average, whereas in high-yield countries, the annual average growth does not surpass 4% (Xu *et al.,* 2018).

In Brazil, the health expenditure corresponds to 8.2% of the GDP, with 4.4% referring to private expenses and 3.8% allusive to the Public Sector. The proportion of public expenditure in the country is close to that of the Latin America and Caribbean average (3.6% of GDP), yet it is far from reaching the average rate of countries in the Organisation for Economic Co-operation and Development - 6.5% of GDP. (National Treasure, 2018). Even in OECD countries where health expenditure represents a higher GDP percentage, there is a growing demand for investments in healthcare (Hadad, Hadad, & Simon-Tuval, 2013).

As shown, economic development requires more lavish public spending on health, so issues related to the sustainability and improvement of a universal health system, such as the Unified Health System (SUS), are high on the political agenda of emerging countries. This group of countries faces an expanding demand for health services which are worsened by population growth and aging, combined with economic and social polarization (Borgonovi & Compagni, 2013).

Apart from health spending relevance, Avelar, Silva, and Fouto (2018) advert that it is essential to take into account the impact of Variation of Medical-Hospital Costs (VCMH) from the Institute of Supplementary Health Studies (IESS), which has been continuously higher than inflation of the national economy. Peña (2008) adds a shortage of resources in both the public and the private sector in the face of ever-increasing demands. This scenario requires of a manager the best combination of resources.

According to Farrell (1957), the efficiency in an organization means its success when producing the maximum possible while maintaining the same inputs, that is, using the same resources. Hence, the permanent seek for efficiency becomes a condition for the hospital organization's survival.

As well as the shortage of resources, pointed out by Peña (2008), another complicating factor for the management of organizations in the health sector, especially for hospital management, is the complexity of these institutions. Hospital units provide a wide range of services, like diagnostics, prevention, treatment, hospitalization, education and research (Silva, Costa, Abbas, & Galdamez, 2017).

Adding to Silva et al. (2017) perspective, Miranda, Carvalho, Martins e Faria (2007) highlight the heterogeneity of "products" offered by the university and educational hospital organizations, which, apart from providing health services to the population, are also responsible for practical training of future health professionals. Lobo, Lins, Silva, and Fiszman (2010) evidenced the existence of multiple dimensions within each of these organizations as an unfolding of the complexity in university hospitals. The cited work identifies the following dimensions: care, teaching, and research.

When assessing the integration of the three mentioned dimensions, Araújo and Leta (2014) identified that, in the view of managers of federal university hospitals, the teaching-care binomial prevails there, to the detriment of research. However, for most managers interviewed by the authors, care (and not teaching) was evidenced as the dimension of the most significant weight.

As for the care dimension, grounded on the present investigation, federal university hospitals oversee offering services for hospitalized patients, upon actions that include health promotion, disease prevention, diagnostic, treatment, and rehabilitation. (Lobo, Rodrigues, André, Azeredo, & Lins, 2016). Since the creation of EBSERH in 2011 (Lei n. 12.550, 2011), the federal university hospitals have been undergoing a redesign in their management model. By analyzing the implementation process of EBSERH, Borges, Barcelos, and Rodrigues (2018) identified the company as a management paradigm for the public sector. In its business management model, there is an intense pressure for efficiency, and the state is seen as one more agent of the economic sphere, historically considered inefficient and little productive.

Bonacim and Araújo (2010) note that in hospitals in general, the staff is funded by their institutors, being, in the case of federal university hospitals, the Ministry of Education. However, funding limited to personnel expenses proves to be insufficient. In this context, reimbursement made by SUS, based on a table that defines a price for each procedure or acquisition of own incomes, displays utmost importance to assure regular functioning. Thus, given the relevance of federal university hospitals management efficiency, the following goal of evaluating the efficiency of care in public hospitals managed by EBSERH is proposed.

As presented, efficiency is a relevant matter for hospital organizations. Although DEA provides information on technical efficiency in hospitals, as opposed to occurrences in the foreign literature, the availability of a great number of studies that make use of this tool is hardly found in Brazil. (Silva, Moretti, & Schuster, 2016).

On the international scope, Kohl, Schoenfelder, Fügener, and Brunner (2019) reviewed publications that made use of DEA. The study in question revised 262 publications that used the data analysis tool in healthcare, emphasizing hospitals. The authors determined that the importance of the matter is not only placed on the number of studies, since a growing number of publications was also verified.

Some national studies that made use of DEA to evaluate efficiency in Brazilian university hospitals (Araújo & Leta, 2014; Lins, Lobo, Silva, Fiszman, & Ribeiro, 2007; Lobo, Silva, Lins, & Fiszman, 2009; Lobo *et al*., 2010, 2016; Lobo, Silva, Lins, Fiszman, & Bloch, 2011; Peixoto, 2016). It is worth mentioning that Lobo *et al*. (2009) research represented a significant contribution for the study of efficiency in Brazilian federal university hospitals when using DEA to verify it in the care and teaching dimensions, acknowledging the importance of measuring efficiency in separate ways once different variables are considered in the estimate of each dimension-related efficiency.

With the advent of EBSERH in 2011, the dimension of care in university hospitals earned relevance because after the change in the management model, "the assistance services provided by these institutions to society and its work capacity are carefully resized to achieve the regional needs and improve economic-financial sustainability of these hospitals" (Empresa Brasileira de Serviços Hospitalares [EBSERH], n.d.b).

More recently, Martini, Machado, Menezes, and Souza (2019) evaluated efficiency focusing on the financial aspect specifically. In the conclusion section, the authors recommended the conduction of new studies using DEA to assess other dimensions, such as care, to insert new variables in the model. It is suggested as an object of future research to evaluate efficiency in university hospitals under the impact of EBSERH adhesion (Martini *et al*., 2019; Peixoto, 2016).

Facing the exposed information, a gap to be fulfilled by the present study is observed for making use of DEA - still barely utilized in the national environment to evaluate university hospitals. With the insertion of relevant variables, as an instance of the hospital occupancy rate, we seek to identify the correlation between the level of social care service efficiency and respective sources of finance costing.

2 THEORETICAL FRAMEWORK

The concepts of efficiency in the public administration and healthcare are thereby presented – the latter being presented through Data Envelopment Analysis (DEA) –, the EBSERH e the quality of provision in federal university hospitals and correlated studies.

2.1 Efficiency in the Public Administration and Healthcare

The principle of efficiency was legally inducted in the public administration by the Constitutional Amendment number 19, of June 4th, 1998 (Constitutional Amendment n. 19, 1998), through which the implementation of a new management model whose primary focus was to improve the allocation of scarce resources was sought, searching for improved technical and operational results, without disregarding the quality of provided services.

The early studies to discuss efficiency in the combination of production factors were developed by Farrell (1957). Regarding the discussion on production efficiency, this author was a pioneer in highlighting the importance of measuring efficiency in an industry and identifying to what extent a given industry can increase production by simply improving its efficiency. In other words, without other resource consumption.

Farrell (1957) inspired Charnes, Cooper e Rhodes' seminal study (1978), which introduced a Data Envelopment Analysis (DEA), known initially as model CCR, in allusion to the creators. This initial model was conceived to analyze Constant Returns to Scale (CRS). The CCR model is used for analysis of cases in which there is a proportionality between input and output (Peña, 2008; Sousa & Ramos, 1999). As an evolution of the CCR model, Banker, Charnes, and Cooper (1984) proposed the DEA model, which further considered Variable Returns to Scale (VRS), known as DEA-BCC.

In the context of public administration, DEA was presented by Peña (2008) as a powerful tool to evaluate the technical efficiency of productive units that user the input to generate goods and services. According to the author, DEA usage is recommended for efficiency-related research in the public administration, once it has been applied successfully in the study of efficiency in public organizations like schools, universities, and health establishments (hospitals and clinics) (Peña, 2008). It is also highlighted studies applied in the allocation of public resources in the Judiciary Branch (Venturin, Souza, & Bianchi, 2020) and the measurement of efficiency in Brazilian soccer clubs (Dantas & Boente, 2012; Nascimento, Nossa, Bermardes, & Sousa, 2015).

The search for efficiency in the health sector is pertinent as the suppliers must be efficient both in cost control and quality of provided services. In the case of public health service, it is necessary to seek its maximization as a premise for the use of public resources or minimization of resource use, maintaining the predefined results (Cesconetto, Lapa, & Calvo, 2008).

As relevant components of the health sector, hospitals constitute, according to Kohl, Schoenfelder, Fügener, and Brunner (2019), the main cost factor for health systems internationally and face a growing pressure to improve efficiency. Nonetheless, hospital efficiency is not a simple task. Among various

tools, DEA earns recognition in the evaluation of efficiency between organizations that are suppliers of health services (Kohl *et al*., 2019).

It is worth mentioning the study conducted by Espejo, Portulhak and Martins (2015), who investigated the management control practices used by federal university hospitals, investigating the size as an explanatory factor of the degree of adoption of such practices. They concluded that the development of managerial control was more advanced in large hospitals.

Given its performance relevance, federal university hospitals have been the subject of a study to understand aspects of its management. As stated by Borges *et al*. (2018), the creation of EBSERH in 2011 projected the adoption of a new business managerial model for federal university hospitals.

2.2 EBSERH and Quality of Social Care in Federal University Hospitals

According to the Federal Medicine Council (CFM), "the university hospitals are training centers for healthcare human resources and technology development" (Conselho Federal de Medicina [CFM], 2019). The CFM also stresses that when providing services to the population, university hospitals carry out permanent care refinement and devise technical protocols for multiple pathologies.

Federal university hospitals play a significant role when performing simultaneously as important human resource training centers in the health sector, supporting research, extension, and teaching activities developed by Brazilian federal universities (EBSERH, n.d.c). In addition to the teaching dimension, university hospitals also contribute remarkably to the care dimension.

As of 2004, implementing the Restructuring Policy of Teaching Hospitals began a more organic integration of the dimensions of teaching and care. In this period, the certification process of university teaching hospitals was initiated with biannual representatives' visits from the Education and Health Ministry. Employing these visits, aspects concerning teaching-health care integration, SUS integration, and management quality became verified (Lobo *et al*., 2010).

According to EBSERH (n.d.b), the federal university hospitals network assembles 50 hospitals linked to 35 federal universities present in all Brazilian regions. In the healthcare sphere, these hospitals are SUS medium to higher complexity reference centers. Out of the 50 hospitals, 40 have signed contracts with EBSERH, which demonstrates the coverage of the new management model performance launched with the company creation.

The creation of EBSERH was authorized by Law n. 12.550, of December 15th, 2011 (Lei n. 12.550, 2011), with the primary goal of:

> free medical-hospital, outpatient care service provision, diagnostic and therapeutic support for the community, as well as provision for federal public education institutions or similar institutions of teaching, research, and extension support, to teaching-learning and staff training in the field of public health, observed in terms of the article 207 of the Federal Constitution, the university autonomy.

In the context of the implementation of EBSERH, an essential aspect of the assistance dimension is the apparent clash between the two management models. EBSERH brought a management model more aligned with the managerial logic of a private company. This managerial alignment with private administration can generate a clash with the principles proposed by SUS management, among them the integrality of care (Borges et al., 2018).

Espejo *et al.* (2015) Espejo et al. (2015) reiterate federal university hospitals' performance relevance through SUS and highlight the importance of research conduction on managerial control practices in establishments, given its relevant role to SUS, above all in the execution of higher complexity procedures. The performance of these institutions in healthcare professional training is also essential to mention, under the law that agreed upon the creation of EBSERH.

2.3 Studies on University Hospitals Efficiency

In a national context, some DEA-based studies to verify efficiency in university hospitals were identified. Lins *et al.* (2007) were pioneers in demonstrating that using DEA was feasible when attesting efficiency in 31 university hospitals. For this purpose, they used variables related to three dimensions: care, teaching, and research, for instance, the number of postgraduate students and the number of Medical Science postgraduate programs. The authors calculated the level of efficiency for each of the three dimensions concluding that regarding the dimension of care, 17 hospitals were considered efficient.

With the goal to evaluate finance reform's impacts on productivity, Lobo *et al*. (2009), upon DEA application, constructed efficiency barriers. To identify development changes caused by financing reforms, the authors calculated the *Malmquist* index in order to identify development changes throughout the quadrennium 2003-2006. It was concluded that financing reforms made possible the development of managerial improvement, considering a more extended period observation would be necessary. In a complementary way, results indicate that one of the main reasons for financing model reform was the necessity to reduce teaching hospitals' health inefficiency (Lobo *et al*., 2009).

Following a similar approach, Lobo *et al*. (2010) assessed performance and integration of the dimensions of care and teaching in federal university hospitals through DEA network application, signaling the importance of including the dimension quality in efficiency evaluations. Lobo *et al*. (2016) also used network DEA variation. This variation considers linking variables that belong in more than one dimension. Such variables are used to analyze efficiency barrier displacement between two periods, in the case of this study, 2010 e 2013.

Nevertheless, some studies about efficiency concerning more than one dimension or solely the financial aspect (Martini *et al*., 2019) in university hospitals were identified (care, teaching, and research). Martini *et al*. (2019) evaluated university hospitals using a census sample, including the five years period 2013-2017. This study only contemplated the financial side, using variables as total financial resources and values from billing of services provided by SUS. Results indicated that UFJF and UFMA university hospitals, alongside HUWC, from UFC, and HESFA, from UFRJ, were considered efficient throughout the period.

Peixoto (2016) has also made use of DEA to assess the federal university hospitals. Based on 2014 data, the author defined variables focusing on the production of resident doctors in various medical specialties, being that variable used as study output.

Thus, the present study is different from the previous ones for shifting focus to the care dimension and for using management indicators and budget information concerning federal university hospital social care provision, which portrays performance under other *relevant* aspects as well, such as quality, aligned with Lobo *et al*.'s recommendations (2010). Furthermore, this study innovates when analyzing the relationship between social care provision and sources of financial costing of university hospitals managed by EBSERH, through a proportion of SUS and their revenue, about the committed expenditure value (EBSERH, n.d.a), a variable which to this moment has not been applied to any previous studies.

3 METHODOLOGICAL PROCEDURES

In regard to methodological framework, the following study consists of qualitative nature. As for the objectives, it is classified as descriptive, in which documental analysis was made use to proceed to data collection on the EBSERH website and SUS Computer Department (DATASUS).

Management indicators and budget information disclosed on monitoring panels provided by EBSERH were used as a database. Those panels are part of a transparency initiative adopted by the company, which utilizes a solution of Business Intelligence to disclose a wide range of information on budget execution and financial, operational, quality, and other indicators (EBSERH, n.d.a). Data from the National Health Facilities Center (CNES) and the data tab TABNET, maintained by DATASUS (Health Ministry, n.d.) were also extracted. Figure 2 details the variables (inputs and outputs) used in the DEA, indicating information source and references to each one.

The collection occurred in December 2019, being used data per the accounting year 2018, as it was, at that time, the most recent with complete data. During the collection, the dashboard presented incomplete information on the indicator's referent to the accounting year 2017, the first year of data disclosure.

The research sample is census-based; in other words, it considered all federal university hospitals that had signed contracts with EBSERH. Figure 1 presents the DMUs (Decision Making Units) used in the study, distributed by states.

Order number	University hospital	Location
1	University Hospital of Brasília (HUB-UnB)	Distrito Federal
2	Clinical Hospital of UFG (HC-UFG)	Goiás
3	University Hospital Júlio Müller (HUJM-UFMT)	Mato Grosso
4	University Hospital of UFGD (HU-UFGD)	Mato Grosso do Sul
5	University Hospital Maria Aparecida Pedrossian (HUMAP-UFMS)	Mato Grosso do Sul
6	University Hospital Professor Alberto Antunes (HUPAA-UFAL)	Alagoas
7	University Hospital Professor Edgard Santos (HUPES-UFBA)	Bahia
8	Maternity Hospital Climério de Oliveira (MCO-UFBA)	Bahia
9	University Hospital Wálter Cantídio (HUWC-UFC)	Ceará
10	Maternity Hospital Assis Chateaubriand (MEAC-UFC)	Ceará
11	University Hospital of UFMA (HU-UFMA)	Maranhão
12	University Hospital Lauro Wanderley (HULW-UFPB)	Paraíba
13	University Hospital Alcides Carneiro (HUAC-UFCG)	Paraíba
14	University Hospital Júlio Bandeira (HUJB-UFCG)	Paraíba
15	Clinical Hospital of UFPE (HC-UFPE)	Pernambuco
16	University Hospital of UNIVASF (HU-UNIVASF)	Pernambuco
17	University Hospital of UFPI (HU-UFPI)	Piauí
18	University Hospital Ana Bezerra (HUAB-UFRN)	Rio Grande do Norte
19	University Hospital Onofre Lopes (HUOL-UFRN)	Rio Grande do Norte
20	Maternity School Januário Cicco (MEJC-UFRN)	Rio Grande do Norte
21	University Hospital of Lagarto (HUL-UFS)	Sergipe
22	University Hospital of Sergipe (HUS-UFS)	Sergipe
23	University Hospital Getúlio Vargas (HUGV-UFAM)	Amazonas
24	University Hospital João de Barros Barreto (HUJBB-UFPA)	Pará
25	University Hospital Bettina Ferro de Souza (HUBFS-UFPA)	Pará
26	Hospital for Tropical Diseases (HDT-UFT)	Tocantins
27	University Hospital Cassiano Antônio Moraes (HUCAM-UFES)	Espírito Santo
28	Clinical Hospital of UFMG (HC-UFMG)	Minas Gerais
29	Clinical Hospital of Uberlândia (HCU-UFU)	Minas Gerais
30	Clinical Hospital of UFTM (HCU-UFTM)	Minas Gerais
31	University Hospital of Juiz de Fora (HUJF-UFJF)	Minas Gerais
32	University Hospital Gaffrée e Guinle (HUGG-UNIRIO)	Rio de Janeiro
33	University Hospital Antônio Pedro (HUAP-UFF)	Rio de Janeiro
34	University Hospital Professor Horácio Carlos Panepucci (HUPHCP-UFSCAR)	São Paulo
35	Clinical Hospital Center (CHC-UFPR)	Paraná
36	Maternity Hospital Víctor Ferreira do Amaral (MVFA-UFPR)	Paraná
37	Teaching Hospital of UFPEL (HE-UFPEL)	Rio Grande do Sul
38	University Hospital of Santa Maria (HUSM-UFSM)	Rio Grande do Sul
39	University Hospital Doutor Miguel Riet Correa Júnior (HUDMRCJ-FURG)	Rio Grande do Sul
40	University Hospital Professor Polydoro Ernâni de São Thiago (HUPPEST-UFSC)	Santa Catarina

Figure 1 – List of DMUs
Source: EBSERH (n.d.a).

DEA has been used to analyze DMUs performance which makes use of the identical inputs to produce the same goods and services (outputs). University hospitals, however, can be framed into the same concept of DMU, as demonstrated by Lins *et al*. (2007).

According to Melo *et al*. (2005), it is necessary to implement three phases in order to apply to the DEA. The first consists of selecting and defining DMUs, in the case of university hospitals managed by EBSERH. The second phase involves variable selection used in DEA. The research variable selection considered previous studies in the area (Figure 2), with data pointing to 2018. The third phase is model selection and application.

The technique assumes as a prerequisite the CCR model, conceived to analyze Constant Returns to Scale (CRS), idealized by Charnes, Cooper, and Rhodes (1978) and the BCC, proposed by Banker, Charnes and Cooper (1984), shifting to Variable Returns to Scale (VRS) (Peña, 2008; Sousa & Ramos, 1999). The result obtained by the model varies between 0 and 1, in which "0" indicates the DMU is inefficient, and "1" means the DMU is efficient (Afonso, Schuknecht, & Tanzi, 2010). In this research, the model DEA-BCC was chosen, with output orientation from Banker *et al*. (1984), which considers variable returns to scale.

The variables presented in Figure 2 were used to calculate social provision efficiency of each university hospital, supported by the Frontier Analyst 4 software. In the processing of DEA, the output-oriented DEA-BCC model was adopted once the intention, through the same level of inputs, is the attainment of improved outcomes.

Variable	Description	Type	Source	Reference
NLeitos	The overall number of beds	*Input*	CNES-DATASUS	Cesconetto *et al.* (2008) Kirigia, Emrouznejad, Sambo, Munguti e Liambila (2004) Tonelotto, Crozatti, Moraes e Righetto (2019)
TGastos	Total committed expenditure value		EBSERH	Silva *et al*. (2017) Tonelotto *et al*. (2019)
Inter	Total of hospitalizations	*Output*	TABNET-DATASUS	Lins *et al.* (2007) Lobo *et al.* (2010) Lobo *et al.* (2011)
TxOcup	Average occupancy rate		EBSERH	Cesconetto *et al.* (2008)
IPerm	Length of stay rate opposite		TABNET-DATASUS	Souza, Nishijima e Rocha (2010)
Imort	Average mortality rate opposite		TABNET-DATASUS	Tonelotto *et al*. (2019) Souza *et al.* (2010)

Figure 2 - Variables used in the study
Source: Elaborated by the authors.

Aiming to group the DMUs by efficiency level, a cluster, or grouping analysis, that consists of an empirical, objective method to put into practice one of the most natural human tasks - classifying, was executed in the aftermath. (Hair, Black, Babin, Anderson, & Tatham, 2009). Therefore, employing this technique, the promotion of university hospital grouping was sought, adopting efficiency level

DEA-based calculation, enabling a 4-group formation: low efficiency, medium-low efficiency, medium-high efficiency, and high efficiency.

From this point on, a correlation *Spearman* test that considers efficiency level and percentage of SUS and hospitals' revenue participation in 2018-based university hospital defrayal was executed. This percentage is made available by EBSERH in its indicator panel. It refers to SUS and hospitals' revenues about the amount of committed expenditure, except for financial resources concerning staff payroll, sentences, and multi-professional residency scholarships (EBSERH, n.d.a). It should be informed that personnel expenses, sentences, and scholarships for values of TGastos indicator purposes are done by EBSERH itself by the organizations' Financial and Budgetary Information Panel.

Likewise, a difference test was adopted between Mann-Whitney non-parametric means. This test is applied for attesting if two samples are derived from the same population. According to the Health Ministry (1977), hospitals can be classified in regard to size as a small, medium, large or special. On account of the 4-size hospital classification, the difference of means test was carried out in pairs. It is worth mentioning that before the non-parametric test application, a normality test was performed, according to which data do not present normal distribution (p-value inferior to 5% significance level). Furthermore, for DEA method-based data analysis, the Frontier Analyst software 4th version was used, while for statistics analysis performance, IBM SPSS Statistics 20 was exploited.

4 ANALYSIS AND DISCUSSION

First and foremost, a descriptive analysis of the variables was conducted. Such analysis permits a more refined comprehension of data behavior, by the identification of trends, the variability, and atypical results (Fávero, Belfiore, Silva, & Chan, 2009). Table 1 illustrates the descriptive statistics of each variable used in DEA.

Table 1
Descriptive statistics of study variables

Variable	Minimum	Maximum	Average	Standard deviation	Variation coefficient (%)
Nleitos	31	653	222	142	63,84
TGastos (R$)	5.525.008,00	489.363.741,00	156.756.834,00	127.041.330,00	81,04
Inter	279	22.193	8.271	5.437	65,74
TxOcup	19	140	70,15	21,52	30,67
Perm	1	18	6,97	2,51	35,98
Mort	0	14	3,69	2,89	78,26

Captions: NLeitos: Overall number of beds, TGastos: Totally committed expenditure value; Inter: Total of hospitalizations; TxOcup: Average occupancy rate; Perm: Length of stay; Mort: Average mortality rate.
Source: Elaborated by the authors.

The Health Ministry (1977) classified hospitals according to their size based on the number of beds. Taking this classification into consideration, the university hospital network which has signed up with EBSERH is formed of multiple-size units,

as can be seen in Table 1. According to Health Ministry parameters (1977), among the 40 sampling DMUs, there are small-sized hospitals (up to 50 beds), medium size (51 to 150 beds), large size (151 to 500 beds), and special size (above 500 beds). The number of beds varies from 31, in the case of HUBFS-UFPA, to 653, CHC-UFPR case.

The total expenditures correspond to the value of committed expenditure by university hospitals in the course of 2018, varying from R$ 5.525.008,00 (HUJB-UFCG) to R$ 489.363.741,00 (HCU-UFU). The maximum and minimum amount of university hospitals expenditure in 2018 reinforce the heterogeneousness of data validated in DEA, which is also evidenced by the confrontation between extreme values and other variables. Hence, in Table 1, it is observed that the variables processed in DEA present the heterogeneous data, being the total of expenses, which represents the value of committed expenditure, the highest variation coefficient.

Another variable that presents a high variation coefficient is that of mortality rate. The fact that both hospitals which presented the highest and the lowest mortality rate are linked to UFPA calls attention. Whereas HUBFS showed the lowest mortality rate in 2018 (null, in fact), CHUJBB marked the highest (14%). It is important to stress that the mortality rate is obtained by the quotient between the number of deaths from patients hospitalized over 24 hours and the output number, multiplying the result by 100. The variable monitors social provision care aiming at the planning of actions that contribute to improved healthcare effectiveness and efficiency (EBSERH, n.d.a), but it presents a limitation due to its complexity.

To identify occasional data redundancy among variables, a correlation test between variables used in DEA was performed, presented in Figure 2. Table 2 presents the results of the Pearson correlation test.

Table 2
Correlation between variables in the study

Variable	*Input*		*Output*			
	Nleitos (I)	TGastos (I)	Inter (O)	TxOcup (O)	IPerm (O)	IMort (O)
Nleitos (I)	1					
TGastos (I)	0,864**	1				
Inter (O)	0,819**	0,739**	1			
TxOcup (O)	0,224	0,112	0,483**	1		
IPerm (O)	-0,355*	-0,192	-0,006	-0,235	1	
IMort (O)	-0,330*	-0,214	-0,070	-0,259	0,641**	1

Captions: NLeitos: Overall number of beds, TGastos: Total committed expenditure value; Inter: Total of hospitalizations; TxOcup: Average occupancy rate; Perm: Length of stay; Mort: Average mortality rate.
Note: (**) Statistics significance of factors to 1% level; (*) Statistics significance of factors to 5% level.
Source: Elaborated by the authors.

According to Table 2, the variables TGastos e NLeitos, both used as inputs, presented a highly-regarded correlation. Peixoto (2016) points out that a reduced correlation between input factors is recommended. However, similarly to Peixoto (2016), the attendance of this aspect was not recognized as fundamental for the present study, given the relevance that the number of beds and financial

resources owe to hospital tasks. The two variables in question are highly used in studies that evaluate hospital efficiency (Kohl *et al*., 2019). According to Lee and Kim (2018), the number of beds is an important indicator since it represents the health infrastructure level. The number of beds can affect the number of hospitalizations, resulting in overcrowding.

Under Table 2, variables NLeitos and Inter presented high correlation, which was expected. Hospitals that have a more significant number of beds, at first, allow a larger number of hospitalizations. As follows, Table 3 presents the result of the efficiency calculation of each DMU, executed by DEA, and respective placement in the efficiency ranking.

Table 3
Efficiency of sampling hospitals

Ranking	DMU	Efficiency Level	Ranking	DMU	Efficiency Level
1º	HU-UNIVASF	100,00	**21º**	HC-UFPE	84,52
1º	CHC-UFPR	100,00	**22º**	HDT-UFT	82,46
1º	HCU-UFU	100,00	**23º**	HUB-UnB	75,93
1º	HUAB-UFRN	100,00	**24º**	HUPHCP-UFSCAR	74,87
1º	HUBFS-UFPA	100,00	**25º**	HUWC-UFC	73,50
1º	HUJB-UFCG	100,00	**26º**	HULW-UFPB	69,38
1º	HU-UFMA	100,00	**27º**	HUPES-UFBA	66,49
1º	MEAC-UFC	100,00	**28º**	MCO-UFBA	64,11
1º	MEJC-UFRN	100,00	**29º**	HE-UFPEL	62,64
1º	MVFA-UFPR	100,00	**30º**	HU-UFPI	61,87
11º	HCU-UFTM	99,25	**31º**	HUJF-UFJF	59,58
12º	HUMAP-UFMS	98,19	**32º**	HUPAA-UFAL	59,55
13º	HC-UFMG	96,31	**33º**	HUJM-UFMT	59,30
14º	HU-UFGD	91,96	**34º**	HUDMRCJ-FURG	57,64
15º	HUSM-UFSM	90,61	**35º**	HUAC-UFCG	57,31
16º	HC-UFG	90,30	**36º**	HUGG-UNIRIO	56,32
17º	HUCAM-UFES	88,73	**37º**	HUAP-UFF	55,00
18º	HUPPEST-UFSC	86,24	**38º**	HUGV-UFAM	51,44
19º	HUL-UFS	86,16	**39º**	HUS-UFS	50,94
20º	HUOL-UFRN	85,39	**40º**	HUJBB-UFPA	36,85

Source: Elaborated by the authors.

According to Table 3, the calculation showed that ten university hospitals reached the efficiency barrier. Among the efficient DMUs, six hospitals are located in the Brazilian Northeast; two in the South, both bound to UFPR; one in the Southeast, and one in the North - the HUBFS-UFPA, whose placement is probably tied with the fact that it reflected the lowest mortality rate of the sample, as seen before.

By using different DMUs, Martini *et al*. (2019) assessed university hospitals' efficiency in the exercise of 2017. They identified that 21 out of 48 analyzed hospitals reached the efficiency barrier employing variables as total financial resources and values of billing from services offered by SUS. Despite the differences in the studied DMUS and the variables adopted in this research, from 10 hospitals that achieved 100% efficiency in this study, seven were also considered efficient

by Martini *et al*. (2019): CHC-UFPR, HCU-UFU, HU-UFMA, HUAB-UFRN, HUBFS-UFPA, MEJC-UFRN e MVFA-UFPR.

We may conjecture that substantially and financially efficient classified university hospitals can be considered as well-performing references, taking into consideration results from both researches. There must be a caveat regarding both pieces having made use of different accounting years (2017 e 2018) and slightly divergent samples in terms of analysed DMUs.

Two hospitals that used exercise quadrennium-related data (2010-2013) and reached the efficiency barrier were also considered efficient by Lobo et al. (2016). Additionally, they estimated efficiency for care, teaching, and research dimensions. The HCU-UFU and the HU-UFMA attained the efficiency barrier in the study mentioned above both in the care dimension and in the total score, which considered the three dimensions.

HCU-UFU, in addition to having been classified as efficient in this study and by Lobo *et al*. (2016) and Martini *et al*. (2019), also reached the efficiency frontier in other studies, such as those of Lins *et al*. (2007) and Lobo *et al*. (2009), regarding the care dimension. For having been identified as efficient in studies that used data from different periods, as well as different variables, the HCU-UFU stands out from the others and can be pointed out as a reference for other university hospitals. At this point, it is worth mentioning that the HCU-UFU has the highest volume of committed expenses.

Among the efficient DMUs, are great-sized hospitals, for example, HCU-UFU that possess 506 beds, and the biggest hospital of the sample CHC-UFPR, which holds 653 beds; small-sized hospitals, as the HUBFS-UFPA, which registered the smallest amount of public expenditure in 2018.

Among the least five efficient university hospitals, two of them are situated in Rio de Janeiro (HUAP-UFF e HUGG-UNIRIO), worth noting that the investigation covered hospitals managed by EBSERH. Although other university hospitals in Rio de Janeiro have not been evaluated, according to the criterion in the sample selection, the two above-mentioned units' low-efficient level calls for the necessity of attention to quality in their social care.

HUL-UFS has also shown a low-efficiency level. Among the units that hold the lowest levels of efficiency, it owns the smallest size, with only 78 beds and a total expenditure of R$ 18.358.608,77 in 2018. The unit pointed as a reference to that DMU, for resembling size, was the HUAB-UFRN (63 beds and expenditure of R$ 11.797.036,74), which reached the efficiency barrier. The performance difference between these two units mainly occurs due to the mortality rate. While the HUL-UFS marked 12,54, the HUAB-UFRN scored 0,24 in 2018.

The HUJBB-UFPA was the worst-performing DMU. Worth mentioning that the full figure of hospital stays mean time (IPerm) and mortality rate (Mort), presented in Table 1, belongs to this hospital, which explains the fact that it presented the lowest level of efficiency amongst all the evaluated units.

In Martini *et al*. (2019), on the financially focused efficiency regarding different DMUs and adopting other variables, in the period analysis 2013-2017 and the exercise of 2017, separately, the HUJBB-UFPA also appears in one of the last positions as to level of efficiency.

Apart from calculating DMUs efficiency, the DEA enables identifying their potential for improvement, in other words, necessary modifications to be implanted so that units categorized as inefficient can achieve the barrier of efficiency. Table 4 shows, in percentages, potential for improvement in the entire sample.

Table 4
Potential for improvement of DMUs

Variables	Potential for improvement (%)
Nleitos (I)	-0,33
TGastos (I)	-0,92
Inter (O)	5,94
TxOcup (O)	2,13
IPerm (O)	2,95
IMort (O)	87,73

Captions: NLeitos: Overall number of beds, TGastos: Total committed expenditure value; Inter: Total of hospitalizations; TxOcup: Average occupancy rate; Perm: Length of stay; Mort: Average mortality rate; (I): Inputs; (O): Outputs.
Source: Elaborated by the authors.

As can be seen in Table 4, in the inefficient DMUs the mortality rate is the variable that deserves more attention, requiring a reduction of 87.73% for the entire group to become efficient. In this sense, this result can contribute to the less efficient hospitals, since the application of DEA generated efficiency patterns that can be mirrored and can guide the policies for the use of available resources in public health care through the university hospitals. The other DEA variables did not present potential for improvement in relevant values.

Scherer *et al.* (2018) compared university hospitals in Algeria, France and Brazil. The study results indicated that, in 2015, emergency services in Algerian and French hospitals presented an occupancy rate superior to 100% in Algeria and 85% in France. In the Brazilian evaluated hospitals, HUB-UnB and HUPPEST-UFSC, the occupancy rate was 47,28% and 75,85% in 2015, respectively. However, in respect to the mortality rate, highlighted as the essential point of attention for Brazilian University Hospitals (HUs), the situation is reversed. In 2015, the HUB-UnB mortality rate was 6,46% and in HUPPEST-UFSC was from 8 to 10%. In the other two countries the percentage was well under: 2,80% in Algeria and 0,4% in France. The comparison of university hospital performance in the three countries reinforces the adequate attention Brazilian management of university hospitals should have with this indicator.

Using the mortality rate as criterion, it is possible to think that adherence to the EBSERH managerial model, by itself, does not guarantee Brazilian university hospitals an improved care performance. In the three countries evaluated by Scherer *et al.* (2018), university hospitals are formed of a management collegiate body; however, in Brazil, the figure of EBSERH emerges with no such equivalent in the other two countries. Scherer *et al*. (2018) indicated some of the problems that might explain the Brazilian hospitals low performance. According to the authors, the two assessed Brazilian hospitals undergo absenteeism and turnover of staff. In the HUPPEST-UFSC, this situation is worsened by the great amount of provision for critically ill patients in a structure and material precarious situation (Scherer *et al*., 2018).

Afterwards, university hospitals were clustered based on the DEA-calculated efficiency (Table 3). For this purpose, based on the cluster analysis, it was possible to determine four different groups in terms of efficiency level: low, medium-low, medium-high, and high. Table 5 shows distribution of DMUs by level of efficiency.

Table 5
Groups of DMUs by efficiency level

Efficiency range	Level	DMU	Number of DMUs	Proportion (%)
0 ≤ x ≤ 36,85	Low efficiency	HUJBB-UFPA	1	2,5
36,85 < x ≤ 66,49	Medium-low efficiency	HUS-UFS, HUGV-UFAM, HUAP-UFF, HUGG-UNIRIO, HUAC-UFCG, HUDMRCJ-FURG, HUJM-UFMT, HUPAA-UFAL, HUJF-UFJF, HU-UFPI, HE-UFPEL, MCO-UFBA, HUPES-UFBA	13	32,5
66,49 < x ≤ 86,24	Medium-high efficiency	HULW-UFPB, HUWC-UFC, HUPHCP-UFSCAR, HUB-UnB, HDT-UFT, HC-UFPE, HUOL-UFRN, HUL-UFS, HUPPEST-UFSC	9	22,5
86,24 < x ≤ 100	High efficiency	HU-UNIVASF, CHC-UFPR, HCU-UFU, HUAB-UFRN, HUBFS-UFPA, HUJB-UFCG, HU-UFMA, MEAC-UFC, MEJC-UFRN, MVFA-UFPR, HCU-UFTM, HUMAP-UFMS, HC-UFMG, HU-UFGD, HUSM-UFSM, HC-UFG, HUCAM-UFES	17	42,5

Source: Elaborated by the authors.

The distribution of DMUs by level of efficiency (Table 5) evidence a higher concentration of high-efficient hospitals (17), followed by the medium-low efficient hospitals (13) and medium-high efficient (9). Only HUJBB-UFPA was classified as low-efficient. Table 6 shows the correlation test results among efficiency levels and hospital costing financial sources in the sample. Worth mentioning that the revenue stream breakdown is not specified by EBSERH in the panel of indicators (collected source), which imposes a constraint in the analysis exposed in Table 6.

Table 6
Correlation between level of efficiency and funding from SUS and hospitals' revenue

Variable	Efficiency calculated by DEA	
	Spearman correlation	Sig
Percentage financed by hospitals' own sources and SUS revenue	0,180	0,266

Source: Elaborated by the authors.

In Table 6, there is no statistically significant correlation verified between efficiency level calculated by means of DEA and the percentage of expenses financed by hospitals' own revenue sources and SUS. Hence, it is not possible to infer that a larger share of own revenues or SUS-based revenues in hospitals funding matrices would proceed to a higher efficiency in social care provision. On the same note, by exploring the relationship between economic financial development and level of efficiency in the hospital context, Oliveira (2016) did not

indicate that efficient hospitals presented greater economic and financial outcomes.

Table 7 displays Mann-Whitney non-parametric test results, which indicates if there is a statistically significant difference between level of efficiency in different-size hospitals (small, medium, large, special).

Table 7
Test of differences between Mann-Whitney means

Null hypothesis	Hospital size	Sig	Decision
Level of efficiency is similar in different-size hospitals	Small and medium size	0,273	Null hypothesis is not rejected
	Small and large size	0,023*	Null hypothesis is rejected
	Small and special size	0,800	Null hypothesis is not rejected
	Medium and large size	0,270	Null hypothesis is not rejected
	Medium and special size	0,287	Null hypothesis is not rejected
	Large and special size	0,014*	Null hypothesis is rejected

Note: (*) statistical significance of 5%.
Source: Elaborated by the authors.

In Table 7, statistically significant differences between DEA-calculated efficiency levels, in the comparison of small- and large-sized hospitals, as well as in the group of large- and special sized hospitals, to the significance level of 5%, are realized. On the other hand, there are no statistically significant differences between the efficiency level in small- and medium-sized hospitals; special and small sized; medium and large sized; and special to medium sized.

The only two small-sized hospitals (HUBFS-UFPA and HUJB-UFCG) presented the higher efficiency means, marking 100,0%. Whereas the group of 25 large-size hospitals presented the lowest efficiency means, of 74,35%. Therefore, even though large-sized hospitals are apparently capable of a more advanced management development control, as claimed by Espejo *et al*. (2015), it did not reflect a higher efficiency rate. The Mendes' hypothesis (2011) was also not confirmed since the adequate number of beds in a university hospital would be ranging from 100 to 450.

Despite the apparent hospitals' efficiency downfall on account of size increase, it is not possible, with grounds on calculated level of efficiency, to infer that performance is prone to a fall given the rise in the number of beds, once special size hospitals, that constitute the biggest number of units (Health of Ministry, 1977), also presented a higher level of efficiency. Among the three sampling hospitals classified as special size, two of them (CHC-UFPR e HCU-UFU) reached the maximum efficiency (100%). This result does not support Mendes' hypothesis (2011) in which diseconomies of scale are becoming important in hospitals with over 650 beds.

5 CONCLUDING REMARKS

Given the relevance of university hospitals in the Brazilian healthcare context not only for its mission to train healthcare workers, but also to play an important role in providing medical care for the impoverished, needy population,

the present study analysed efficiency in social care provision of 40 university hospitals managed by EBSERH.

Results indicated that 10 out of 40 analyzed university hospitals reached the 100% efficiency index. Yet, it was verified that seven out of ten hospitals that achieved the care-dimension efficiency barrier were also nominated as efficient by Martini *et al*. (2019) research, in terms of financial aspects in different DMUs upon distinctive variables. Thus, the university hospitals classified as efficient either surrounding the dimension care and the financial aspect can be possibly regarded as well-performing references, taking into account results from both researches. This analysis was made possible by the model used in the study - DEA, which generated scores for each DMU, in this case, for each hospital, and the high-achieving or more efficient DMUs become benchmarks to the least efficient.

The study revealed that, among the efficient-achieving hospitals there is no specific size predominance, to which the same applies for low-achieving efficient hospitals. Despite large-sized hospitals leading to a more advanced and developed management control, as determined by Espejo *et al*. (2015), this fact did not converge to a more elevated efficiency index.

Taking into consideration the average efficiency level of large-sized hospitals, it was also not corroborated by the hypothesis raised by Mendes (2011), of which the adequate number of beds in a hospital range from 100 to 450, once this group displayed the lowest average efficiency index. Another claim that was not impacted in the sampling university hospitals efficiency indexes was that diseconomies of scales for hospitals with more than 650 beds exist. Additionally, comparing the list of efficient-classified hospitals in other pieces of research, the HCU-UFU stands out with the highest value of committed expenses. The mentioned hospital was also considered efficient by Lins *et al*. (2007), Lobo *et al*. (2009, 2016) and Martini *et al*. (2019).

The study sample, limited to 40 federal university hospitals managed by EBSERH, included only two hospitals located in the state of Rio de Janeiro. Notwithstanding little representativity, two fluminense hospitals belong to a group of DMUs with worst indicators of efficiency.

It should be highlighted that, as for coming improvements in the group of university hospitals aiming to reach the efficiency barrier, it was determined that the most deserving-of-attention variable is the mortality rate, with the urge of 87,73% reduction in the current framework so that the entire sampling group becomes efficient. Regarding the potential for improvement, it is worth highlighting that Barreto (2015) ascertains that pay for performance has been widely defended as a strategy to implant behavioral changes in health service providers, be it in the individual or collective level. Therefore, pay for performance can be an improvement alternative for the mortality rate indicator in the context of university hospitals managed by EBSERH.

It is not possible to infer that prioritizing care through SUS or obtaining its own revenues reflects greater efficiency in social care. This was identified from the results of the correlation test, which indicated that there is no statistically significant correlation between the level of efficiency of social care provided by hospitals and the percentage of expenses funded with own and SUS revenue sources.

The application of the test of differences between means showed the existence of significant differences between efficiency levels when comparing groups of hospitals by size, in the case of small and large hospitals. The group of small-sized hospitals, for instance, reached the maximum efficiency (100%). The special size group of hospitals also performed well, showing significant differences in efficiency when compared to the large size group of hospitals. The worst performance observed, considering the average of the efficiency indexes, was the group of large-sized hospitals.

As limitations of the research, we mention the fact that at the time of collection, complete data were not available in the EBSERH indicator panel for other years. Regarding the definition of the sample, it was not possible to include university hospitals not linked to EBSERH, since the main source of data, in this case the indicators panel, only discloses data from hospitals managed by EBSERH. Another limitation of the study is that the efficiency calculated through DEA did not consider the procedures performed, the type of specialization and the level of complexity of the university hospitals analyzed.

As for the suggestion for future research, it is recommended that new performance indicators be added to the model, as well as other university hospitals that do not have a contract with EBSERH. Another suggestion for future research is to try to identify the relationship between the level of efficiency of university hospitals and the stage of implementation of the EBSERH management model, not investigated in this research.

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AUTHORS' CONTRIBUTIONS

Contributions	Samuel Cavalcante Mota	Antonio Rafael Valério de Oliveira	Alessandra Carvalho de Vasconcelos
1. Idealization and conception of the research subject and theme	✓	✓	✓
2. Definition of the research problem	✓	✓	✓
3. Development of Theoretical Platform	✓	✓	
4. Design of the research methodological approach	✓	✓	✓
5. Data collection	✓	✓	
6. Analyses and interpretations of collected data	✓	✓	
7. Research conclusions	✓	✓	
8. Critical review of the manuscript			✓
9. Final writing of the manuscript, according to the rules established by the Journal.	✓	✓	✓
10. Research supervision			✓