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Good practices in the management of medical gases in teaching hospitals in Brazil: situational diagnosis

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Abstract

Objective: To characterize compliance with good practices in medical gas management in federal teaching hospitals in Brazil. **Methods:** A cross-sectional survey-type study, designed to perform a situational diagnosis of the pharmacy services in 40 federal teaching hospitals in Brazil linked to the Brazilian Hospital Services Company, with respect to compliance with good practices in gas management, through the application of the ABPGasMed 1.0 instrument. This instrument consists of 54 compliance standards divided into two sections (structure and process). The characterization of research participants and hospitals, and the classification of hospitals in terms of performance categories were expressed as absolute and relative values. Chi-square tests of independence were performed to investigate the association between the hospital's performance category and the hospital's geographic region and size. **Results:** In total, 87.5% of the invited hospitals participated in the study, and only 27.59% of the hospitals had a pharmacist responsible for medicinal gases. Pharmacovigilance was performed by pharmacists in 20.59% of the hospitals. Analyzing the hospitals by region of the country and size, statistically significant associations were found between the general classification of hospitals and the geographic region ($x^2(8)=18.936$, p= 0.015), as well as the classification of the hospital and structure and size ($x^2(9)= 20.373$, p= 0.016). Analyses of the adjusted standardized residues returned an association between the southeastern region and the satisfactory performance category when analyzing the entire instrument, and between the excellent performance category in the structure section and size of a small hospital. **Conclusion:** In most of the hospitals studied, management of medicinal gases did not show the desired performance, which indicates the need to comply with current healthcare legislations and improve the provided services. It is believed that compliance rates may evolve training of healthcare team members, with an emphasis on the pharmacist.

Keywords: gases; therapeutic uses; good practices; analysis of situation; hospital.

Boas práticas de gestão de gases medicinais em hospitais de ensino no Brasil: diagnóstico situacional

Resumo

Objetivo: Caracterizar o cumprimento das boas práticas na gestão de gases medicinais em hospitais federais de ensino no Brasil. **Métodos:** Estudo transversal do tipo survey, no qual foi realizado um diagnóstico situacional do cumprimento das boas práticas com os gases medicinais nos serviços de farmácia de 40 hospitais federais de ensino do Brasil, por meio da aplicação do instrumento ABPGasMed 1.0, que consiste em 54 padrões de conformidade divididos em duas seções (estrutura e processo). A caracterização dos participantes da pesquisa e dos hospitais, e a classificação dos hospitais quanto às categorias de desempenho foram expressos por meio de valores absolutos e relativos. Foram realizados testes de qui-quadrado de independência para investigar associação entre a categoria de desempenho do hospital e a região geográfica do hospital e seu tamanho. **Resultados:** No total, 87,5% dos hospitais convidados participaram do estudo e apenas 27,59% dos hospitais possuíam farmacêutico responsável pelos gases medicinais. A farmacovigilância era realizada por farmacêuticos em 20,59% dos hospitais. Analisando os hospitais por região do país e porte, foram encontradas associações estatisticamente significativas entre a classificação geral dos hospitais e a região geográfica (x2 (8) = 18,936, p = 0,015), bem como a classificação do hospital e estrutura e tamanho (x2 (9) = 20,373, p = 0,016). As análises dos resíduos padronizados ajustados mostraram que houve associação entre a região Sudeste e a categoria de desempenho satisfatório na análise de todo o instrumento, e entre a categoria de desempenho excelente no seção estrutura e ser um hospital de pequeno porte. **Conclusão:** Na maioria dos hospitais estudados a gestão dos gases medicinais não apresentou desempenho desejado, apontando a necessidade de cumprimento da legislação sanitária vigente e do aprimoramento dos serviços prestados. Acredita-se que os índices de cumprimento podem evoluir com a capacitação dos membros da equipe de saúde, com ênfase no farmacêutico.

Palavras-chave: gases; usos terapêuticos; boas práticas; análise de situação; hospital.

Introduction

Medical gases are considered medicines or medical devices in several countries, particularly in the European Union, Asia, and the Americas.[1-5] These gases can be isolated or associated with each other and used in diagnosis, life support, prevention, and treatment of several diseases, such as hypoxemic respiratory failure related to infection caused by the Sars-CoV-2 virus, COVID-19.[6,4,7] In addition, medicinal gases can be used in surgical procedures as anesthetics, for insufflation in laparoscopic surgery, or as sources of pneumatic energy for surgical and dental instruments. They are also prescribed as drug vehicles.[5,8,9]

With the inclusion of medicinal gases in the official list of essential medicines prepared by the World Health Organization, there is a concern by health regulatory agencies worldwide regarding the good practices that should be established for the manufacture and use of these medicines.[2,10,3,11-13] In hospitals, healthcare professionals must be trained in accordance with good practices from receipt of these substances, to monitoring of their use, and to provide adequate management of these drugs in patient care.[14,15,4]

The management of medical gases for human use is among the duties of hospital pharmacy services, as well as those responsible for their use in clinics and home care.[16-18] According to Luisetto and Sahu[6], the management of medicinal gases by hospital pharmacists results in support for healthcare teams and better handling of these drugs, improved quality control and risk management, containment of costs, and enhanced promotion of patient safety.[19,20]

In 2008, Brazil began considering medical gases as medicines and hospital pharmacists as responsible for their logistical cycle.[21,22] After 13 years of regulation, little is known about compliance with good hospital practices with medicinal gases and the role of the pharmacist in this process, since the evaluation of hospital pharmacies has not focused on this area or included strategies for these analyses.[2,12,23-25]

According to Donabedian[26], the evaluation of the quality of health services, including those provided by pharmacists, can be performed by the triad of structure, process, and results. According to the World Health Organization[27], pharmacists must ensure that services are of an appropriate quality, based on good pharmacy practices, with a focus on the patients' health. Despite the literature citing the negative impacts of the misuse of medicinal gases, there is no general data on the quality of their management in more than 6,700 Brazilian hospitals.[28,15,29] Therefore, the aim of this study was to characterize compliance with good practices in the management of medicinal gases in federal teaching hospitals managed by the Brazilian Hospital Services Company (EBSERH).

Methods

A cross-sectional, multicenter study was conducted using a survey approach.[30] Data was retrieved directly from the interest group in order to assess compliance with good practices in the management of medical gases in pharmacy services of federal teaching hospitals in Brazil.

The survey was conducted nationwide with pharmaceutical professionals or those responsible for the management of medical gases at their institutions. All 40 federal public teaching hospitals affiliated with the Brazilian Hospital Services Company (EBSERH) were invited to participate. Hospitals affiliated with EBSERH were chosen for the study because they have a national distribution and a standardized management model, as well as an ease of access for managers (convenience sample).

To preserve identity, codes were defined for each hospital studied, where H represents the word Hospital, and the following letters represent the region of Brazil in which the hospital was located (CO, Midwest; N, North; NE, Northeast; SE, Southeast; and S, South). The letter was followed by a sequential number.

The ABPGasMed 1.0 – Good Hospital Practices with Medicinal Gases evaluation instrument was applied online using the Google Forms platform. This survey was developed by the authors based on international and Brazilian regulations and on studies obtained through a literature review, and was subsequently validated by a panel of experts who comprised a nominal group.[31] The instrument was based on the SPO model (Structure, Process, and Results) proposed by Donabedian[32] to assess the quality of health services and has 54 compliance standards divided into sections of 29 structure standards and 25 process standards. Among the 54 compliance standards, seven were classified as moderately critical and the others as extremely critical.

The coordinators of the pharmacy services of the invited hospitals received a link to the evaluation instrument via e-mail. If the pharmacy was not responsible for the management of gases, the link was shared with the service manager responsible for the gases. An informed consent form was provided for completion by the professionals who agreed to participate in the research. The participants then answered items regarding the characterization of the institutions and professionals responsible for completing the survey. Finally, the participants utilized the ABPGasMed1.0 instrument by answering questions in a dichotomous way (yes or no) regarding compliance with the standards of structure and process compliance, and indicated "does not apply" when the compliance standard was not relevant.

During the study, the instrument was available for 70 days, between October 2018 and January 2019, with an estimated completion time of 18 min. During the time the instrument was available for application, three reminders were sent (one every 20 days) to the coordinators of the pharmacy services of the hospitals.

All responses were tabulated using an Excel® spreadsheet (version 15.19.1). Data related to the characterization of research participants and hospitals, and the classification of hospitals according to performance categories were expressed using absolute and relative values. The overall compliance rates separated by hospital and section (structure and process) were expressed using relative values. The percentages of compliance with the good practices of each hospital were calculated according to the two sections of the instrument (structure and process), as shown in Figure 1. The items assessed by the participants as "not applicable" were disregarded.

Scores of compliances with standards according to the degree of criticality proposed by the ABPGasMed 1.0 instrument were calculated by section of the instrument (structure and process) and in general, providing those hospitals were classified into performance categories as proposed in Table 1.

Figure 1. Calculation of percentages of compliance with the compliance standards for the structure and process sections.

$$\%\text{compliance}_{\text{structure}} = \left(\frac{n(compliant)}{29 - n\,(does\ not\ apply)}\right) x100$$

$$\%\text{compliance}_{\text{process}} = \left(\frac{n(conforme)}{25 - n\,(does\ not\ apply)}\right) x100$$

Table 1. Performance categories, their respective scores and colors proposed by ABPGasMed 1.0[31].

Performance category	Color	Extremely critical	Moderately critical
Excellent	Blue	≥90%	100%
Satisfactory		≥90%	≥50% e <100%
Satisfactory	Green	≥80% e <90%	≥50%
Satisfactory		≥70% e <80%	100%
Little satisfactory	Yellow	≥80% e <90%	<50%
Little satisfactory		≥70% e <80%	<100%
Unsatisfactory	Red	<70%	≤100%

Based on the classification of performance categories, chi-square tests of independence (4 × 5 /4 × 4) were performed in order to investigate whether there were associations among hospital classification (unsatisfactory, little satisfactory, satisfactory, and excellent) for sections of structure, process, and in general; the geographic region of the hospital (north, northeast, southeast, south, and midwest); and its size (small, medium, large, and special).

The study was approved by the Research Ethics Committee of the Federal University of Sergipe (opinion no.: 3,709,534; CAAE: 22984119.9.0000.5546). The participants were previously informed about the goals and voluntary nature of the study.

Results

Of the 40 hospitals invited to participate in the study, 35 responded to the instrument, representing a participation rate of 87.5%. The professionals responsible for the application of the instrument in the institutions were mainly women (n= 23; 65.7%), 32 to 51 years of age (n= 25; 71.4%), pharmacists (n= 26; 74.3%), with more than ten years of professional experience (n= 25; 71.4%). The characteristics of the studied hospitals, such as size and location by region of the country, and whether located in the capital or in the countryside, are described in Table 2.

In view of the structure of the instrument applied, in which the compliance standards are distributed in two sections, the calculation of the index of compliance with good hospital practices with medical gases from the institutions followed the division described in Tables 3 and 4.

Table 3 shows the rate of compliance with good hospital practices with medical gases from the hospitals studied in regard to the "structure section" compliance standards. Hospitals showed compliance percentages that ranged between 10.71% and 100%, for compliance standards one and six, which are related to the legal requirement of a pharmacist in this activity (27.29%) and the presence of a protective screen, respectively. The point of capture in medical air compressors (10.71%) had an inferior evaluation.

Table 2. Characteristics of the 35 studied hospitals.

Information	n (%)
Hospital size (number of beds)	
Small (≤50)	2 (5.71)
Medium (51-150)	12 (34.29)
Large (151-500)	19 (54.29)
Special (>500)	2 (5.71)
Region	
North	3 (8.57)
Northeast	17 (48.57)
Midwest	4 (11.43)
Southeast	6 (17.14)
South	5 (14.29)
Located in the state capital or inland	
Capital	24 (68.57)
Inland	11 (31.43)

Table 4 shows the rate of compliance with good hospital practices with medicinal gases with regard to the compliance standards of the process section. The hospitals showed compliance percentages for each process standard that varied between 20% and 97.14%, and standards one and three, which are related to the direct performance of a pharmacist, had the lowest evaluation rates.

Table 5 shows the percentage of compliance with good hospital practices with medical gases per hospital and according to each section.

After calculating the scores according to the percentage of compliance with the compliance standards separated by the degree of criticality proposed by the ABPGasMed 1.0 instrument, hospitals were classified into performance categories, as shown in Table 6.

Table 7 reveals that a significant association was found between the general classification of hospitals and the geographic region ($x^2(8)= 18.936$, p= 0.015), as well as the classification of the hospital and structure and size ($x^2(9)= 20.373$, p= 0.016). No significant association was found between the general classification and the hospital size ($x^2(6)= 8.722$, p= 0.190), structure classification and geographic region ($x^2(12)= 17.565$, p= 0.130), process classification and geographic region ($x^2(12)= 15.375$, p= 0.222), process classification and hospital size ($x^2(9)= 7.868$, p= 0.548). Analyses of the adjusted standardized residues returned an association between the northeast region and the unsatisfactory general classification, the southeast region and the satisfactory general classification and, finally, the excellent structure classification and small hospitals.

Table 3. Structure compliance standards in the 35 studied hospitals.

Information	n/N (%)[1]
Structure compliance standards	
Does the hospital have a pharmacist registered as responsible for medicinal gases in the local Pharmacy Council?	8/35 (22.86)
If the hospital uses a medical compressed air supply unit with a compressor, does it have another central unit with a compressor, or at least two cylinders connected to a network?	28/28 (100.00)
Is the suction of medical air compressors located outside the building, capturing atmospheric air free of any contamination from exhaust systems, such as ovens, combustion engines, hospital vacuum discharges and solid waste removal?	20/29 (68.97)
Is the air intake point for medical air compressors located at a minimum distance of three meters from any door, window, building entrance or other access points?	18/28 (64.29)
Is the air intake point of medical air compressors located at a minimum distance of sixteen meters from any ventilation exhaust, vacuum pump discharge or bathroom exhaust?	14/27 (51.85)
Does the air intake point of medical air compressors maintain a distance of six meters above the ground, with the end of the air inlet protected by a screen and facing downwards?	3/28 (10.71)
If the hospital uses a central with a special supply of 21% of oxygen and 79% of liquid nitrogen to produce and distribute synthetic compressed air, does it have a backup supply and a continuous analysis system that blocks the supply when out of specifications?	5/9 (55.56)
If the hospital uses the reservoir by cryogenic tank, does it have at least two reserve cylinders connected to a network?	31/31 (100.00)
Is the installation site of the central reservoir or the oxygen concentrating generator located at ground level?	30/33 (90.91)
Does the installation site of the central reservoir or oxygen generator comply with the minimum distance of five meters from the building area?	16/34 (47.06)
Does the installation site of the central reservoir or oxygen generator comply with the minimum distance of five meters from the combustible materials area or storage of flammable materials?	30/35 (85.71)
Does the installation site of the central reservoir or oxygen generator comply with the minimum distance of five meters from an audience meeting place?	20/35 (57.14)
Does the installation site of the central reservoir or oxygen generator comply with the minimum distance of three meters from doors or passageways that give access to the storage area?	22/35 (62.86)
Does the installation site of the central reservoir or oxygen generator comply with the minimum distance of three meters from vehicle traffic area?	21/35 (60.00)
Does the installation site of the central reservoir or oxygen generator comply with the minimum distance of three meters from public sidewalks?	17/35 (48.57)
Is the installation site of the central reservoir or oxygen generator located outdoors or in a fireproof shelter?	32/35 (91.43)
Is the installation site of the central reservoir or oxygen generator protected from the risk of falling electric power transmission lines or pipes containing flammable liquids or fuel, or flammable gases?	31/34 (91.18)
In the centralized gas system, are signs used to indicate the persons authorized to have access?	24/35 (68.57)
In the centralized gas system, are signs used to indicate the procedures to be adopted in case of emergencies, the telephone number to be used in these cases and with signs adverting to danger?	19/35 (54.29)
Is the surface, where the gas plant is located, made of non-combustible material and compatible with cryogenic temperatures?	33/35 (94.29)
Is there sufficient lighting to allow adequate viewing of the supply center at night?	29/35 (82.86)
Does the institution use an alarm system for failure monitoring in the supply center?	30/35 (85.71)
Is the installation site for the oxygen central reservoir easily accessible to maintenance and supply personnel?	35/35 (100.00)
Is the cylinder storage area covered, dry, clean, well ventilated and protected from sunlight?	32/35 (91.43)
Does the gas storage location have a fire extinguisher?	29/35 (82.86)
Does the hospital have a package insert or chemical safety information sheet for the available gases?	18/35 (51.43)
Does the institution provide personal protective equipment (colorless safety goggles, boot with protective toecaps and leather scrape gloves or vaquel exclusive for this purpose and free of oil or grease) for the transportation of cylinders?	16/35 (45.71)
Are the places, where life support equipment is usually used, provided with an emergency supply of oxygen and compressed air for each equipment?	25/34 (73.53)
Does the hospital have a standard operating procedure for receiving, storing and distributing medical gases?	14/35 (40.00)

[1]Dichotomous variable for the quality presented only the answer 'yes'. The items assessed by the participants as "not applicable" were disregarded.

Table 4. Process compliance standards in the 35 studied hospitals.

Information	n/N (%)[1]
Process compliance standards	
Is the pharmacovigilance of medicinal gases performed by a pharmacist?	7/34 (20.59)
Is the prior authorization of the occupational physician required for pregnant women to carry out activities in the area with medicinal gases or anesthetic vapors?	11/27 (40.74)
Is the reception of medicinal gases carried out or supervised by a pharmacist?	7/35 (20.00)
During the reception of medicinal gases, is there an evaluation regarding the compliance of transport practices?	18/34 (52.94)
When receiving liquid oxygen, is the product quality certificate required, with batch analysis, dated and signed by a legally qualified professional?	27/34 (79.41)
Is the certificate provided by the company at the time of delivery filed for a minimum period of one year after the product expires?	26/33 (78.79)
When the cylinder is received, is its batch, validity and identification checked?	20/35 (57.14)
Are all cylinders of the piped system backup supply connected to the collector and with the respective valves open?	33/35 (94.29)
Are tests performed periodically to evaluate the automatic activation of the reserve supply when the minimum safety pressure of the primary supply is reached?	18/34 (52.94)
Are the gas central reservoir maintenance programs and reports available to the work team?	22/35 (62.86)
Are cylinders stored away from grease or other combustible materials, as well as from flammable gases?	33/35 (94.29)
Are the cylinders stored upright by a strap, chain or other similar material?	25/35 (71.43)
If the hospital uses flammable gases such as hydrogen and acetylene, are they stored at a minimum distance of eight meters from oxidizing medicinal gases, such as oxygen and nitrous oxide, or separated by fire-resistant barriers?	15/21 (71.43)
Are cylinders kept away from sparks, flames and other sources of heat above 54°C?	35/35 (100.00)
Are empty cylinders stored separately from the full ones?	33/35 (94.29)
Are damaged or suspected cylinders identified, segregated and reported?	34/35 (97.14)
Are the safety recommendations provided by the manufacturer accessible to workers?	19/35 (54.29)
Was the team that handle the cylinders properly trained?	28/35 (80.00)
During the process of changing the cylinder valves, is a specific tool used to avoid the greases and other combustible materials?	28/32 (87.50)
Is the helmet or seal removed only when the cylinder is to be used?	30/35 (85.71)
Are adaptations made to the cylinder connections?	7/35 (20.00)
Are the cylinders cleaned before being taken to the operating room?	10/32 (31.25)
Are the cylinders transported in an upright position?	31/35 (88.57)
Are oxygen, compressed air and other gases used only for the purposes for which they are intended?	32/35 (91.43)
Is the prohibition on transferring gas from one cylinder to another respected?	34/35 (97.14)

[1]Dichotomous variable for the quality presented only the answer 'yes'. The items assessed by the participants as "not applicable" were disregarded.

Table 5. Compliance of structure and process standards by hospital**.**

Hospital	Structure compliance standards (%)	Process compliance standards (%)
HNE09	93.10	81.80
HN02	92.86	91.30
HS05	86.21	68.00
HCO04	85.71	86.40
HSE02	5.71	84.00
HSE04	83.33	52.00
HS04	82.14	95.70
HS03	79.31	100.00
HSE03	79.31	91.30
HSE05	75.00	80.00
HCO02	72.00	72.70
HCO03	71.43	80.00
HNE04	71.43	78.30
HNE12	71.43	76.00
HN03	70.83	79.20
HNE08	70.83	75.00
HNE02	67.86	84.00
HNE03	67.86	70.80
HNE05	67.86	58.30
HNE13	67.86	41.70
HNE17	67.86	66.70
HCO01	66.67	75.00
HN01	66.67	65.20
HNE06	64.29	65.20
HNE14	64.29	72.00
HSE01	62.96	70.80
HNE10	59.26	56.00
HS01	57.14	76.00
HS02	54.55	40.00
HNE15	53.57	37.50
HNE16	53.57	64.00
HNE11	50.00	50.00
HSE06	50.00	69.60
HNE07	46.43	79.20
HNE01	45.83	75.00

*HS= South Region Hospital; HNE= Northeast Region Hospital; HN= North Region Hospital; HCO= Midwest Hospital; HSE= Southeast Region Hospital

Table 6. Distribution of hospitals by performance category of each compliance standard and general.

Indicator	n(%)N n (%)
Structure	
Unsatisfactory	21 (60.00)
Little satisfactory	4 (11.40)
Satisfactory	9 (25.70)
Excellent	1 (2.90)
Process	
Unsatisfactory	16 (45.70)
Little satisfactory	6 (17.10)
Satisfactory	11 (31.40)
Excellent	2 (5.70)
General	
Unsatisfactory	21 (60.00)
Little satisfactory	5 (14.30)
Satisfactory	9 (25.70)

Table 7. Analysis of association between hospital classification for the structure and general section with geographic region and hospital size using the chi-square test of independence.

Information	General classification of hospitals			
	Unsatisfactory	**Little satisfactory**	**Satisfactory**	**Excellent**
Hospital geographic region				
North (n)	0	2	1	-
Adjusted residuals	-2.2	2.7	0.3	-
Northeast (n)	14	2	1	-
Adjusted residuals	2.6[1]	-0.4	-2.6	-
Southeast (n)	2	0	4	-
Adjusted residuals	-1.5	-1.1	2.5[1]	-
South (n)	3	1	1	-
Adjusted residuals	0	0.4	-0.3	-
Midwest (n)	2	0	2	-
Adjusted residuals	-0.4	-0.9	1.2	-
Hospital size	**Classification of the structure section of hospitals**			
	Unsatisfactory	**Little satisfactory**	**Satisfactory**	**Excellent**
Small (n)	0	0	1	1
Adjusted residuals	-1.8	-0.5	0.8	4.1[1]
Medium (n)	9	1	2	0
Adjusted residuals	1.3	-0.4	-0.9	-0.7
Large (n)	11	3	5	0
Adjusted residuals	-0.3	0.9	0.1	-1.1
Special (n)	1	0	1	0
Adjusted residuals	-0.3	-0.5	0.8	-0.2

n= number of hospitals; [1]$p < 0.05$

Discussion

The characterization of hospital pharmacies is commonly found in the literature; however, no studies have been noted that identify compliance with good hospital practices for medicinal gases.[30,25,23,33] Therefore, this study is a pioneer in describing compliance with good practices with medical gases by hospital pharmacies. In view of the results obtained, the evaluation instrument applied can be an important tool for health inspections and self-inspections for hospitals of any size, allowing for realization of situational diagnoses and facilitating the planning of strategies for structural and procedural improvement.

Despite the regional inequalities of a continental country like Brazil, as well as the challenges imposed by the responsibilities and daily processes inherent to a hospital pharmacy, those responsible for the majority of federal teaching hospitals participated in the study and responded to the instrument within the stipulated period. A survey study conducted between 2015 and 2017 in the United States to evaluate practices in hospital pharmacies showed a low response rate (x= 22.3%).[34-36] Another study conducted in 2018 with 35 countries in Europe, evaluated the implementation of European declarations for hospital pharmacy, with an approximately 14% response rate.[37] The great adherence of the institutions participating in the current research may be justified by the fact that the studied hospitals develop studies frequently, as well as the ease of the data collection method and all hospitals were already being asked to pass the medicinal gases management to pharmacists. Despite the fact that the majority of the structural standards were complied with by most of the hospitals evaluated in this study, there was a lower frequency of some relevant requirements, such as the provision of standard operating procedures and personal protective equipment. The literature and international legislation emphasize that hospital management must prioritize patient safety, but because of the nature of gases, which are often oxidizing or flammable, they must also guarantee institutional safety and protect those involved in the handling of these products.[4,38-41,13,42-44,14] Thus, the standards that were not met may be restrictive to the hospitals in the study, but they warn of the need for continuous assessments of the safety and adequacy of all institutions.

With regard to the structure, in addition to having professionals responsible for this activity in hospitals, it is necessary to be concerned with the human resources in training. The literature shows that it is only possible to reduce errors related to the administration of medical gases when there is investment in the training of health professionals, as well as in the definition of multiprofessional strategies that guarantee more safety in all stages of the process from receiving to administration and monitoring.[45-47] Therefore, it is necessary to invest in the training of pharmacists and their continuous upgrading, as well as in the inspection of the structure and processes by health agencies.[48,6]

According to the literature, continuous training and adequate compliance with these standards promote increased safety for professionals and patients, and aid in cost reduction.[14,15,4,6,48] This training should remind professionals of the importance of proper fulfillment of activities, including those that are fundamental such as ensuring the receipt of medical gases in the necessary and adequate quantities, avoiding the undue exchange of gases, and confirming that the cylinders are sealed, non-violated, and identified, as well as the assessment of good distribution practices by suppliers.

Although recommended by Brazilian legislation in 2008, the management of medical gases by pharmacists was considered low in the present study.[21,22] The instrument used defines different weights for each conformity standard according to the criticality. Thus, the absence of a pharmacist responsible for the logistical cycle of medical gases is classified as extremely critical, as this can impact the fulfillment of other standards, especially those related to processes. These data can be corroborated by a French study that observed medication errors in the use of medical gases reported by health professionals, in particular the exchange of oxygen by the oxygen/nitric oxide mixture, leading to serious adverse events, damage, and death.[15] These facts reinforce the importance of the role of the pharmacist with medical gases, since, as for any medication, the dispensing of medicinal gases must follow protocols and routines that promote patient safety and avoid the exchange of the distributed gases. After the application of the instrument in the present study, the Brazilian public company, which manages the participating hospitals, demanded the transfer of responsibility for the management of medical gases to the hospital pharmacy service.[49]

A study by Orchiston[50], through the identification of care errors, describes the importance of pharmacist accountability in the processes of elaborating and implementing protocols for receiving, storage, and transportation. Other studies have highlighted the importance of processes relating to being carried out by properly trained professionals, including pharmacists. [4,48,6] However, in Brazil and certain countries in Europe and Asia, pharmacist training is directed towards performing industrial activities or laboratory science, and withdrawal from activities such as the management of medicinal gases.[51-54]

As with any medication, the risks associated with the use of medical gases must be considered, and consequently, an appropriate process must be implemented in the hospital environment, ensuring safety for professionals and patients, with lower care costs.[47,55] According to the literature, these gases can cause adverse events, requiring care from production to utilization.[56-58] A study that analyzed the French database on medication errors and the national pharmacovigilance database from 1985 to 2014 identified 42 reports of improper use of medical gases, including four risks of medication errors, four near errors/failures, and 34 medication errors.[15] Of these errors, 18 led to an adverse effect, seven were considered serious according to the pharmacovigilance criteria, and three were fatal.

A study carried out in Brazil analyzing the characteristics of adverse events related to health care resulting in death that were registered in the Health Surveillance Notification System from June 2014 to June 2016, showed only three cases associated with medical gases, representing 0.03% of notifications.[59] The present study revealed that most hospitals were classified as unsatisfactory in terms of compliance with the structure and process standards related to medical gases; therefore, these institutions are vulnerable to the risks associated with the use of these drugs, reinforcing the need for short- and medium-term adjustments.

The current study showed an association between the excellent structure classification and small hospitals, possibly because small hospitals have low technological density and are easier to manage than larger institutions. Although the majority of hospitals in Brazil are small, they account for only 18% of hospital beds.[60] A study conducted by Scherer et al.[61], which evaluated public university hospitals in Algeria, Brazil, and France, identified infrastructure deficit among the main challenges for institutions, and that measures to rationalize and contain costs are prioritized when there is a low level of public funding.

The association between the location of the hospital in the southeastern region of the country with a satisfactory general classification, and the unsatisfactory classification in the northeastern region links the structural and procedural differences identified in the study to remnants of the reality of this sector in Brazil that was the subject of discussion between 2003 and 2004. This made it possible to propose hospital reform and the adoption of the National Hospital Care Policy in 2013, with the objective of responding to the population's health needs. This situation was aggravated by the disarticulation of hospitals with the rest of the assistance network and by the concentration of these resources in medium and large cities in the south and southeast regions.[62,63] Although the current management of the studied hospitals is carried out by the same company, it took place only a short time before this study. This situation highlights the importance of complying with good practices in hospitals, in a planned manner, according to the local reality, with the aim of standardization of quality and safe care in the country.

As in this study, audits suggest that the use of medical gases, such as oxygen, by health professionals is not compatible with international protocols.[64,65] Therefore, compliance with good practices for medical gases in hospitals is essential, particularly during a time of worldwide shortage, for patients with decreased saturation (satO2 < 94%), or for patients who, in addition to the decrease in saturation, show symptoms of acute respiratory failure, ventilatory effort, or even as a result of partial pressure of O2 in the arterial blood (PaO2) presented in the blood gas analysis below 63 mmHg, who used oxygen through orotracheal intubation.[66-68]

The present study had some strengths and limitations. Although the results helped the studied hospitals to identify their weaknesses and plan solutions, further studies are needed to re-assess the reality of hospitals regarding any procedural changes made, and studies with a longitudinal design are suggested. Although the hospitals are managed by the same company, the study sample may be considered heterogeneous, as it involved professionals with different backgrounds and cultures, and institutions with organizational differences. Since medical gas management is a new role for pharmacists, difficulties in the interpretation of compliance standards may be present in our study. To the best of our knowledge, this is the first study to characterize compliance with good hospital practices of medical gases, and a representative sample is presented. Thus, future research should propose the evaluation of different hospitals worldwide, reinforcing the importance of this activity for the greater effectiveness of the processes used to obtain positive results for patient health and safety.

Conclusion

Although the management of medical gases in the studied hospitals did not reveal the desired outcome, it was possible to identify institutions with a good level of performance. In addition, hospital management is in search of compliance with the current sanitary legislation, and consequently the improvement of the services provided. Such an initiative has the potential to promote protection of the institution's physical structure, safety of professionals and patients, and reduction of care costs. Compliance rates can evolve with the training of health team members, particularly pharmacists. Therefore, it is expected that the instrument used and the data obtained will serve as references for the adequacy of hospitals in Brazil and worldwide.

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Collaborators

FJA, LCS, IMB, LMA and DLJ were responsible for the study conception and design, FJA, LCS, FAN, DCA, DLJ and IMB were responsible for the data analysis and interpretation, FJA, LCS, FAN, LMA and DCA were responsible for writing the article, IMB and DLJ were responsible for the relevant critical review of the intellectual content. All authors are responsible for all information in the work, ensuring accuracy and integrity of any part of it.

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Declaration of conflict of interests

The authors declare that there are no conflicts of interest regarding this article.

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