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Original article

Correlation of Oxygen Consumption and Patient Day with Invasive Mechanical Ventilation in a Hospital in Sao Paulo during Covid-19 Pandemic

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Abstract

Background: The new coronavirus led the world into the pandemic known as COVID-19. Still, without any effective treatment, oxygen therapy is the most used treatment for patients. Without proper management of this medicinal gas, lives can be lost for lack of it. ***Aim:*** Find an indicator of a strong correlation with oxygen consumption. ***Methods:*** A single-center retrospective study, that evaluated the oxygen consumption billing data and patient-day indicator of Central Institute of HCFMUSP between 2019 and 2020. ***Results:*** A total of 380,245 patient days were analyzed. A strong correlation was identified between oxygen consumption and patient day with invasive mechanical ventilation (0.92). An average of 41.6 (± 7.8) cubic meters per patient day with invasive mechanical ventilation was found. Conclusion: There is a strong correlation between oxygen consumption in cubic meters and patient days with invasive mechanical ventilation at the Central Institute of HCFMUSP. The average values of consumption per patient day can help in planning oxygen management in other hospitals.

Keywords: ***pandemic, oxygen consumption, public health, indicators, healthcare, invasive mechanical ventilation***

Introduction

The sudden surge of severe acute respiratory syndrome coronavirus (SARS-CoV-2), caused by a novel RNA coronavirus named COVID-19 that prompted the World Health Organization (WHO) to declare a pandemic, named COVID-19, on March 11, 2020, [1] has affected the health management of countries around the world[2].

Still without an effective treatment, since the beginning of the pandemic, the use of oxygen has been the most used therapy to treat patients [3,4], and sustainable access to oxygen has been a challenge in low- and middle-income countries [5].

In these countries, hospitals are running out of oxygen, which makes the management of this supply essential for the healthcare of patients affected by COVID-19, where its lack can mean loss of life [6,7].

Despite this importance, there is little data on the consumption of this material in hospitals, which could be used for planning and action in times of health crisis.

To fill this knowledge gap, the authors carried out a survey of oxygen consumption at the Central Institute of Hospital das Clínicas of the University of São Paulo School of Medicine (HCFMUSP) and correlated it with one of the most common indicators of hospital management, the patient day.

Objective

This study aims to seek a correlation between oxygen consumption and the patient day and look for an index that can be used for planning the use of oxygen by hospitals.

Methods

Study Type

This is a single-center retrospective study.

Study Setting

The study was carried out using Oxygen consumption billing data and the Patient-Day indicator of the Central Institute of HCFMUSP.

Population and Sample

A survey of oxygen consumption billing and amount regarding patient-days was conducted in the Central Institute of HCFMUSP between the periods January 2019 to December 2020.

A total of 380,245 patient-day, all anonymous, were found. For each patient-day was checked the use of invasive mechanical ventilation was by medical order from the electronic medical record (EMR).

Data Collect and Analysis

The data was extracted in Excel version 2010 Microsoft Inc® from the Billing System and EMR.

Excel´s Pivot Table was used for calculating the mean, percentages, standard deviation e correlation.

Variables

Oxygen consumption is taken from the billing system in cubic meters by month.

Patient day and patient day with invasive mechanical ventilation by medical order is taken directly from the EMR and grouped by corresponding month.

A rate of invasive mechanical ventilation (RIMV) was obtained by dividing the patient day with invasive mechanical ventilation by the total patient day of the corresponding month.

Oxygen consumption per patient day with invasive mechanical ventilation was obtained by dividing the total oxygen consumed in cubed meter by the total patient day with invasive mechanical ventilation of the corresponding month.

Results

Patient-Day and Invasive Mechanical Ventilation

As shown in Table 1, in 2019, the rate of invasive mechanical ventilation (RIMV) inpatient days ranged between 9% to 12%, as well the first quarters of 2020, ranging between 12% to 14%. As soon as the COVID-19 breakout in Sao Paulo, the RIMV increased to 41% in April, peaking at 48% in the months June and July, with a gradual decrease down to 16% in December of 2020.

Table 1: Patient day, a patient day with the use of invasive mechanical ventilation and rate of use of invasive mechanical ventilation along 2019 to 2020

Year	Month	Patient Day	Patient Day with IMV	RIMV
2019	January	17.899	2.045	11%
	February	16.940	1.706	10%
	March	17.990	1.658	9%
	April	17.969	1.935	11%
	May	18.593	2.036	11%
	June	17.531	1.764	10%
	July	18.634	1.914	10%
	August	18.695	2.003	11%
	September	17.865	1.838	10%
	October	17.552	1.760	10%
	November	16.848	1.574	9%
	December	16.731	1.993	12%
2020	January	18.247	2.114	12%
	February	16.371	1.821	11%
	March	15.398	2.083	14%
	April	9.556	3.962	41%
	May	15.603	6.738	43%
	June	15.124	7.202	48%
	July	10.353	4.923	48%
	August	8.312	3.001	36%
	September	12.345	2.515	20%
	October	15.110	2.111	14%

	November	15.297	2.105	14%
	December	15.282	2.413	16%

IMV = invasive mechanical ventilation
RIMV = Rate of invasive mechanical ventilation

Oxygen Consumption

As shown in Table 2, the oxygen consumption ranged from 65 thousand cubic meters to 80 thousand cubic meters in 2019, and increased along the months of 2020, peaking at 240 thousand cubic meters in June of 2020 and ending 2020 at 142 thousand cubic meters in December.

Table 2: Oxygen Consumption, Patient Day, and Patient Day with invasive mechanical ventilation along 2019 to 2020 by month.

Year	Month	Oxygen Consumption in a cubic meter	Patient Day	Patient Day with IMV
2019	January	76.924	17.899	2.045
	February	73.428	16.940	1.706
	March	69.314	17.990	1.658
	April	69.726	17.969	1.935
	May	80.010	18.593	2.036
	June	70.343	17.531	1.764
	July	67.874	18.634	1.914
	August	79.392	18.695	2.003
	September	66.949	17.865	1.838
	October	75.793	17.552	1.760
	November	65.715	16.848	1.574
	December	75.382	16.731	1.993
2020	January	86.590	18.247	2.114
	February	72.191	16.371	1.821
	March	90.292	15.398	2.083
	April	123.301	9.556	3.962
	May	205.441	15.603	6.738
	June	240.107	15.124	7.202
	July	169.121	10.353	4.923
	August	159.667	8.312	3.001
	September	131.975	12.345	2.515
	October	111.619	15.110	2.111
	November	117.389	15.297	2.105
	December	142.604	15.282	2.413

IMV = invasive mechanical ventilation

Applying the correlation test for the variable oxygen consumption was obtained a result of -0.60 when matching with the variable patient day, and 0.92 when matching with the variable patient day with invasive mechanical ventilation Indicating that the variables oxygen consumption and patient day with invasive mechanical ventilation have a strong positive linear correlation (**Table 3**).

Table 3: Correlation of Oxygen Consumption with Patient Day, and Correlation of Oxygen Consumption with Patient Day with invasive mechanical ventilation.

Variables	Correlation (R)
Oxygen Consumption and Patient Day	- 0.60
Oxygen Consumption and Patient Day with IMV	0.92

IMV = invasive mechanical ventilation

Due to the strong positive linear correlation, a patient day with invasive mechanical ventilation was used to obtain the index oxygen consumption per patient day.

As shown in Table 4, the consumption ranged from 35.5 to 43.1 cubic meters per patient day in 2019. And in 2020, ranging from 30.5 to 43.3 cubic meters per patient day until July, with an increase in the last five months, ranging from 52.5 to 59.1 cubic meters per patient day.

The average oxygen consumption was 41.6 (± 7.8) for the 2019 and 2020 periods, 39.3 (± 2.7) in 2019, and 43.9 (± 10.4) in 2020 (Table 5).

Table 4: Oxygen Consumption along 2019 to 2020 by month and per patient day with invasive mechanical ventilation.

Year	Month	Oxygen Consumption in a cubic meter	Patient Day with IMV	Oxygen Consumption per Patient Day with IMV
2019	January	76.924	2.045	37,6
	February	73.428	1.706	43,0
	March	69.314	1.658	41,8

	April	69.726	1.935	36,0
	May	80.010	2.036	39,3
	June	70.343	1.764	39,9
	July	67.874	1.914	35,5
	August	79.392	2.003	39,6
	September	66.949	1.838	36,4
	October	75.793	1.760	43,1
	November	65.715	1.574	41,8
	December	75.382	1.993	37,8
2020	January	86.590	2.114	41,0
	February	72.191	1.821	39,6
	March	90.292	2.083	43,3
	April	123.301	3.962	31,1
	May	205.441	6.738	30,5
	June	240.107	7.202	33,3
	July	169.121	4.923	34,4
	August	159.667	3.001	53,2
	September	131.975	2.515	52,5
	October	111.619	2.111	52,9
	November	117.389	2.105	55,8
	December	142.604	2.413	59,1

IMV = invasive mechanical ventilation

Table 5: Oxygen Consumption per Patient Day with invasive mechanical ventilation per periods

Year	2019 and 2020	2019	2020
Mean	41,6	39,3	43,9
SD	7,8	2,7	10,4

Discussion and Analysis

The variable with the greatest comparison for resource consumption in the hospital is the patient day. A patient day is a unit of measure that represents the care provided to an inpatient during a hospital day [8].

It is a widely used measure in the area of hospital management based on the construction of other indicators to assess productivity in hospitals [9], or for team sizing [10].

This way, when the indicators are simple to obtain and easy to understand, it helps managers in the art of hospital administration, from its planning to its execution [11].

Having a strong correlation between oxygen consumption in cubic meters and patient day with invasive mechanical ventilation, the average value of 41.6 cubic meters of consumption per patient day with invasive mechanical ventilation opens away in hospital management of medicinal gases, instead of the common Vendor Managed Inventory Supply Chain System model [12].

With this average value found, it can be estimated, for example, in a field hospital with 1,000 beds for COVID-19, a tank of 50 to 60 thousand cubic meters per day is needed. As the lack of oxygen in a crisis like COVID-19 can mean loss of life, contingency measures such as one or two reserve tanks of the same size can be planned.

Therefore, the importance of this indicator of oxygen consumption per patient day with invasive mechanical ventilation.

Limitations

This study is based on a single-center experience and results may not be widely generalizable.

The 2-year study period is short and it is not possible to state the result of the long-term average, being necessary the elaboration of further studies and future research.

Conclusions

There is a strong correlation between oxygen consumption in cubic meters and patient days with invasive mechanical ventilation at the Central Institute of HCFMUSP.

The average values of consumption per patient day found can help in planning oxygen management in hospitals.

Abbreviations

EMR: Electronic Medical Record
HCFMUSP: Hospital das Clínicas of the University of São Paulo School of Medicine
IMV: Invasive Mechanical Ventilation
RIMV: Rate of Invasive Mechanical Ventilation
RNA: Ribonucleic Acid
SD: Standard Deviation
WHO: World Health Organization

Declarations

Ethics approval and consent to participate

This is a study about management and process improvement, there was no need to go through the ethics and research committee evaluation.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Authors' contributions

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References

[1] WHO. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020 Available from: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020. Acess at 2021.Jun.

[2] Gagliano A, Villani PG, Co' FM, Manelli A, Paglia S, Bisagni PAG, et al. COVID-19 Epidemic in the Middle Province of Northern Italy: Impact, Logistics, and Strategy in the First Line Hospital. Disaster med. public health prep. 2020;14(3):372-6.

[3] Melesse DY, Chekol WB. The management of patients with coronavirus disease 2019 in intensive care unit (ICU) in low income countries: A review article. Clin Nutr Open Sci. 2021;37:60-72.

[4] Kluge S, Janssens U, Welte T, Weber-Carstens S, Marx G, Karagiannidis C. German recommendations for critically ill patients with COVID-19. Med Klin Intensivmed Notfmed. 2020;115(Suppl 3):111-4.

[5] OPAS OP-AdS. Emergência de oxigênio devido à COVID-19 afeta mais de meio milhão de pessoas em países de baixa e média renda todos os dias Organização Pan-Americana da Saúde: Organização Pan-Americana da Saúde; 2021 Available from: https://www.paho.org/pt/noticias/25-2-2021-emergencia-oxigenio-devido-covid-19-afeta-mais-meio-milhao-pessoas-em-paises. Acess at 2021.Jun.

[6] Lavor Ad. Amazônia sem respirar: falta de oxigênio causa mortes e revela colapso em Manaus. 2021. Available from: https://www.arca.fiocruz.br/handle/icict/46768. Acess at 2021.Jun.

[7] Uchoa P. Para além de Manaus, pandemia provoca crise do oxigênio em três continentes. BBC News Brasil. 2021. Available from: https://www.bbc.com/portuguese/internacional-55856813. Acess at 2021.Jun.

[8] Brasil. Ministerio da Saude. Secretaria de Assistencia a Saude. Departamento de Sistemas e Redes A. Padronização da nomenclatura do censo hospitalar: Brasil. Ministerio da Saude; 2002. Available from: https://bvsms.saude.gov.br/bvs/publicacoes/padronizacao_censo.pdf. Acess at 2021.Jun.

[9] Bittar OJNV. Produtividade em hospitais de acordo com alguns indicadores hospitalares. Rev. Saúde Pública. 1996;30(1):53-60.

[10] Min A, Scott LD. Evaluating nursing hours per patient day as a nurse staffing measure. J Nurs Manag. 2016;24(4):439-48.

[11] Lima-Gonçalves E, Aché CA. O hospital-empresa: do planejamento à conquista do mercado. Rev. adm. empres. 1999;39(1):84-97.

[12] Pereira SEH. Utilização da prática de VMI no abastecimento de oxigênio em um hospital público. 2012. Available from: http://iepapp.unimep.br/biblioteca_digital/pdfs/docs/11102013_151209_suelen.pdf. Acess at 2021.Jun.