Original

Estimating and Projecting Demand for Azithromycin Antibiotic in Khartoum State, Sudan

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Abstract

Objectives: This study presents a simple method to estimate the real supply and demand for azithromycin (AZA) antibiotic in 2022 and project its demand for the next 10 years in Khartoum State, Sudan.

Methods: A descriptive cross-sectional market survey was conducted in three cities of Khartoum State from February 2022 to November 2022 by visiting 85 pharmacies. Basic questions were asked to the pharmacist through a questionnaire regarding the actual supply and demand of AZA.

Results: The obtained data showed an actual supply of 158,386,750 AZA tablets/capsules and a real demand of 633,547,000 tablets/capsules in 2022. In addition, this study found that there was a gap between the supply-demand of approximately 668 million of AZA tablets/capsules until 2031. **Conclusions:** This study can be used as a guide to estimate the actual supply and the real demand for AZA antibiotic or any other antibiotic and to predict its real demand for the future.

Keywords

Azithromycin, actual supply, market survey, real demand, Sudan

Introduction

The projection of future trends adds value to the improvement in supply and determines the actual supply and real demand for medicine in the current global affairs trend [1]. According to the World Economic Forum, projecting data on drug supply and demand would be used extensively to predict the treatment of unknown diseases [3,2]. The growth of drug supply and demand in the health care sector consists of adapting and pivoting to remain relevant in the marketplace. In general, health care businesses cannot be expected to grow due to changing demand, but your supply chain does not account for that change. Even with rapid supply chain growth, projection models can maintain a high level of performance by providing trend information based on observational data [2,4].

Medicines supply quantification in the process of calculating the quantities necessary for a certain health program and determining when the medical item should be delivered to guarantee that the intended service is continually given to the intended users. For reliable and successful medicine supply, information about consumption data, prescriptions and morbidity data are required [4,5]. This high complex process entails predicting the number of essential medicines required and serves as a basis for determining the appropriate quantity to procure.

In Sudan, the medicine supply is controlled by the federal and state Departments of Pharmacy. These two sectors work collaboratively to ensure that medicines having certain qualities regarding efficacy, safety standards and affordability. To fulfill this job, a solid system for medicine supply including registration and pharmacy premises licensing is followed by federal and state Departments of Pharmacy 6].

The demand for medicines in Sudan has been increased rapidly in the last two decades. These might be due to the population growth, increasing numbers of

local pharmaceutical manufacturers and pharmacies across the country. In addition, the population's financial ability to purchase medicines and the availability of improved health supplies might also participate in the demand growth. As the consequence, the increased demand has added an additional burden to federal and state Departments of Pharmacy to create effective tools for assessing the real demands of medicines and drug supply in the country [5,6].

According to the World Health Organization, infection is considered as the most important contributor to human morbidity and mortality until recent times. It affects millions of people worldwide and its treatment cost is high in different human societies [7].

Azithromycin (AZA), a chemical analog of erythromycin, and belongs to a macrolide antibiotic group. AZA is an acid-stable and orally active antibiotic candidate [8]. It has a similar spectrum of antibacterial activity with other macrolides such as erythromycin; However, AZA is more active than erythromycin against many Gram-negative pathogens and several other pathogens, notably *Haemophilus influenzae*, *Moraxella catarrhalis*, *Neisseria gonorrhoeae*, *Ureaplasma urealyticum* and *Borrelia burgdorferi* [9]. In Sudan, AZA is among the most common antibiotic drugs that are dispensed without medical prescription.

The objective of this study is to estimate the real supply and demand for AZA in 2022 years in Khartoum State, Sudan. In addition, this study aims to project the real demand for this antibiotic to the next 10 years.

Methods

Study design

A cross-sectional survey was conducted by visiting 85 pharmacies (n = 85) within Khartoum State cities (Khartoum, Omdurman and Khartoum-North), Sudan to determine the annual consumption of AZA antibiotic from February 2022 to August 2022. In this study, the geographic

distribution and the number of pharmacies in the three main cities were as follows: 34 pharmacies in Khartoum, 34 pharmacies in Omdurman, and 17 pharmacies in Khartoum-North.

In Khartoum State, Sudan, medicines are dispensed by both the public and private healthcare sectors. The public healthcare system is governmental pharmacies, while the private sector consists of private pharmacies [10].

In this study, all factors were considered during the market survey such as type of pharmacy (both governmental and private sectors pharmacies were visited equally); location (both pharmacies in the middle and around the cities were visited equally), and population density.

Collection and analysis of data

To collect accurate data, questions were asked directly to pharmacists through a simple questionnaire. The questions were related to the annual sales of AZA antibiotic (in any dosage form and strength) and whether AZA is dispensed with a medical prescription; the types of infections that can be treated by AZA; and many others. The questionnaire was constructed to contain 4 open questions and three close-ended questions.

1. How many AZA capsule/tablet did you dispense per month?
   ....
2. Did you dispense AZA capsule/tablet with or without medical description?
   …………………………………………
3. Please mention the most common types of infectious diseases for which you have dispensed AZA
   a. ....
   b. ....
   c. ....
   d. ....
   e. ....
2. Did you agree that the AZA supply is sufficient for domestic consumptionis?
   a. Very much agree
   b. Agree
   c. Disagree
   d. Very much disagree

4. Do you agree that we need to establish new factories to fill the shortag of AZA in Sudan?
    a. Very much agree
    b. Agree
    c. Disagree
    d. Very much disagree
5. Do you agree that the AZA price is affordable for patients from the layers of society?
    a. Very much agree
    b. Agree
    c. Disagree
    d. Very much disagree
6. Please mention the most common side effects that you are informed from your patients after dispensing AZA?
    ....

Ethical considerations

As no individual data were used in this analysis, no ethical approval was necessary under the applicable Napata College's Ethical Guideline.

Statistical analysis

Data analysis was performed using Microsoft Excel 2010 and GraphPad prism version 8.0.2. Tables and figures were used to display the outcomes. Student's t-test was used to determine the significance of differences between dispensing of AZA with or without medical prescription. P-value < 0.05 was considered statistically significant.

Results

Collection and analysis of data

The sales per year for AZA tablets/capsules from pharmacies in the Khartoum state were collected. The sale of AZA per year in pharmacies for Khartoum city is shown in Table 3.1, for Omdurman city it is shown in Table 3.2 and for Khartoum North is shown in Table 3.3. In addition, the overall sale of AZA per year for the three cities is summarized in the Fig. 3.1.

Table 3.1. Annual sale of AZA in Khartoum City's Pharmacies

No.	Pharmacy Code	Sale of AZA tablet/capsule per year
1.	A1	1350
2.	B1	900
3.	C1	300
4.	D1	900
5.	E1	320
6.	F1	600
7.	G1	1500
8.	H1	2000
9.	I1	600
10.	J1	720
11.	K1	400
12.	L1	900
13.	M1	320
14.	N1	1800
15.	O1	4500
16.	P1	4500
17.	Q1	900
18.	R1	900
19.	S1	2700
20.	T1	270
21.	U1	1200
22.	V1	2800
23.	X1	1800
24.	Y1	1350
25.	Z1	2700
26.	AA1	300
27.	BB1	4500
28.	CC1	54
29.	DD1	270
30.	EE1	900
31.	FF1	4500
32.	GG1	360

33.	HH1	900
34.	II1	450
Total		48,464

Table 3.2. Annual sale of AZA in Omdurman City's Pharmacies

No.	Pharmacy Code	Sale of AZA tablet/capsule per year
1.	A2	900
2.	B2	1350
3.	C2	900
4.	D2	450
5.	E2	630
6.	F2	90
7.	G2	4500
8.	H2	4600
9.	I2	6000
10.	J2	9000
11.	K2	180
12.	L2	3000
13.	M2	2700
14.	N2	270
15.	O2	90
16.	P2	360
17.	Q2	270
18.	R2	270
19.	S2	1350
20.	T2	3000
21.	U2	2250
22.	V2	900
23.	X2	2100
24.	Y2	270
25.	Z2	1200
26.	AA2	750
27.	BB2	900

28.	CC2	900
29.	DD2	1350
30.	EE2	450
31.	FF2	750
32.	GG2	300
33.	HH2	600
34.	II2	200
Total		52,830

Table 3.3. Annual sale of AZA in Khartoum-North City's Pharmacies

No.	**Pharmacy Code**	**Sale of AZA tablet/capsule per year**
1.	A3	1180
2.	B3	9000
3.	C3	450
4.	D3	1350
5.	E3	2700
6.	F3	4500
7.	G3	900
8.	H3	5000
9.	I3	6000
10.	J3	4200
11.	K3	2600
12.	L3	1350
13.	M3	7500
14.	N3	900
15.	O3	2100
16.	P3	4500
17.	Q3	1800
Total		57,100
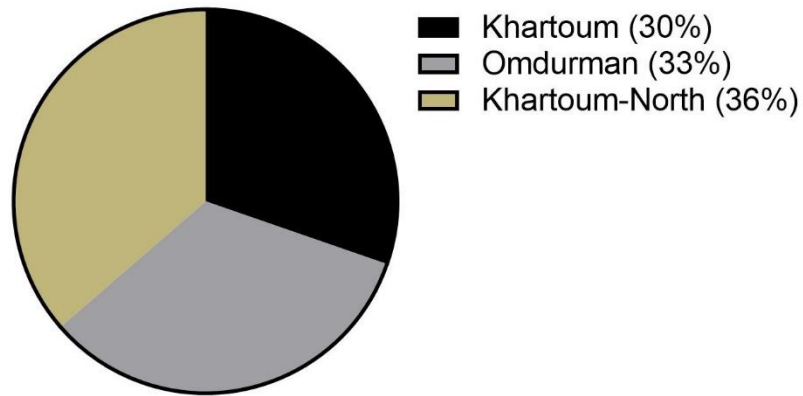
Fig. 3.1. AZA consumption percentage per year in the three cities of Khartoum State

AZA dispensing among pharmacists

Fig. 3.2: shows the dispensing practice of AZA among pharmacists in community pharmacies in Sudan. As shown in the figure, AZA the dispensed by community's pharmacist without medical prescription were more than with a medical prescription. Approximately 55% of pharmacists involved in this study replied that they dispense AZA without receiving the medical prescription compared to 45% with medical prescription ($p < 0.05$).
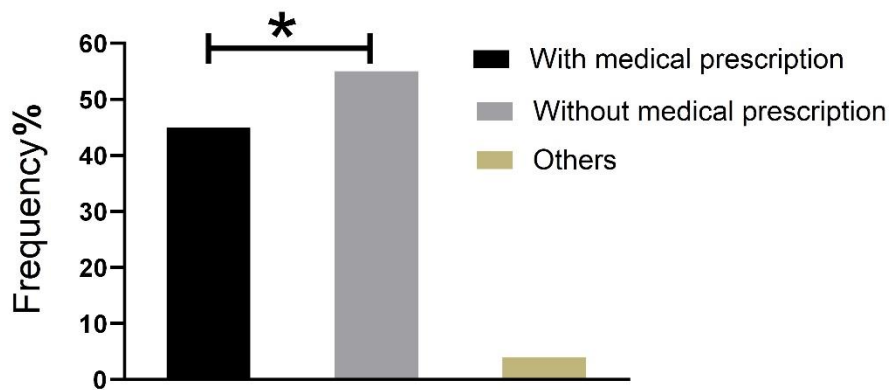
Fig. 3.3. Dispensing practice among pharmacists in community pharmacies in Sudan.

Types of infections treated by AZA

. **Fig.** 3.3: shows the most common types of infectious diseases that can be treated by AZA in Sudan. The most common type of infection treated by AZA reported by the pharmacists was upper respiratory tract infection (59%), lower respiratory tract infection (26%), urinary tract infection (14%), skin infection (9%) and genital infection (8%).
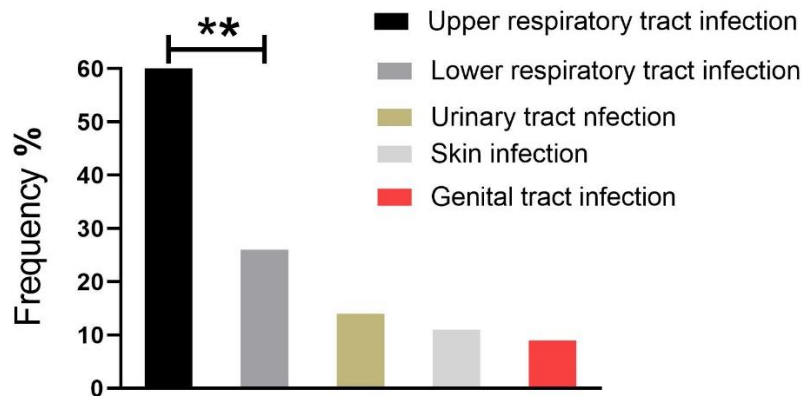

Fig. 3.3. The types of infectious diseases that treated with AZA in Sudan.

Affordability of AZA

Fig. 3.4: shows AZA price affordability to patients. As shown in the figure, > 70 % of the pharmacists involved in the survey replied that the current price of AZA is affordable for the most of their patients.
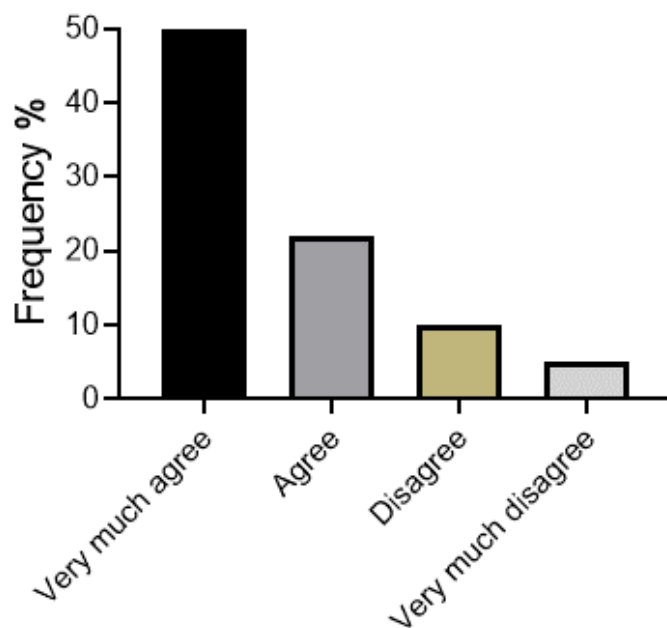
Fig. 3.4: AZA affordability to patients.

AZA consumption in Khartoum State

To assess the real demand for AZA antibiotic per year in Khartoum State, the obtained data were analyzed by using the drug-consumption data approach.

The consumption of AZA (tablet and capsule) per year in the visited pharmacies can be calculated as following:

= Total annual consumption= total annual consumption of Khartoum + total annual consumption of Omdurman State + total consumption of sale of Khartoum North State

= 48,464 + 52,830 + 57,100 = 158,390 tablets/capsules.

The number of pharmacies in Khartoum State, including both private and governmental, is equal to 9,550 pharmacies (the General Directorate of Pharmacy, Sudan, 2022). Therefore, the total annual consumption of AZA of one pharmacy in Khartoum state can be calculated as following:

= Total annual consumption of one pharmacy in Khartoum State = Total annual consumption of 85 pharmacies ∕ number of pharmacies

= 158,390 9,550 = 16,585 tablets/capsules.

The total consumption of AZA antibiotic in Khartoum state can be estimated as following: = Total annual consumption of AZA of one pharmacy total number of pharmacies

= 16,585 × 9,550 = 158,386,750 tablets/capsules.

AZA real demand calculation

The World Health Organization (WHO) recommended a minimum of US 12 $ for individual consumption, while the actual consumption by the Sudanese citizen is equal to only US 3 $ as documented by the Ministry of Health-WHO recently [10,11]. To reach the minimum level of consumption recommended by WHO in this study, the total sale of AZA antibiotic in Khartoum State in 2022 will be multiplied by factor 4. = 158,386,750 × 4 = 633,547,000 tablets/capsules.

AZA demand projection

Calculation of the real demand of AZA antibiotic for the following 10 years was estimated for 10 years by taking 3% as the population growth rate (WHO, 2015). Table 3.4 shows the demand projection for AZA starting from 2022 until 2031.

Table 3.4. The real demand projection for AZA tablets and capsules in the coming 10 years

No,	Year	The real demand
1.	2022	633,547,000
2.	2023	652,553,410
3.	2024	672,130,012
4.	2025	692,293,912
5.	2026	713,062,729
6.	2027	734,454,610

7.	2028	756,488,248
8.	2029	779,182,895
9.	2030	802,558,381
10.	2031	826,635,132

AZA Supply projection

To project the supply of AZA antibiotic for the coming 10 years in Khartoum State, the total gap of AZA between the real demand and actual supply can be calculated as follows:

= Total gap = Demand project for 2031 - Total AZA supply

= 826,635,132 – 158,386,750 = 668,248,382 tablets/capsules.

Discussion

To facilitate comparison of health care outcomes between countries around the world, WHO has developed a standardized method for measuring drug supply and demand [12]. In its methodology, the WHO recommends the list containing 14 medicines from different therapeutic groups prescribed in most parts of the world. The supply of drugs, including AZA generally depends on the quantity in stock in pharmacies. In addition, the price of the medicine is a key factor linked to the supply and demand of the medicine. When the price is more affordable, more people can buy them, and the supply declines [13]. In contrast, when the price is high, fewer people buy them while the supply remains high, and so more medicines remain on store shelves in pharmacies [14]. In Sudan, the price of the full course of the AZA antibiotic is about $US 2, which makes it affordable for many patients, and this was reflected in the survey result as a high annual sale of it by each pharmacy in the three cities (Table 3.1, 3.2 and 3.3). The patients' median price ratio for AZA in the private retail pharmacies is lower compared to pharmacies in public hospitals [15].

In this study, based on the projected 2031 estimate, there is a gap of over 668,000 tablets/capsules of AZA in market demand in Khartoum state, Sudan. This means that the real demand for AZA antibiotics in the Sudanese pharmaceutical market will be greater than the actual supply. In a developing country such as Sudan, pharmacists and their assistants often dispense medicines, such as AZA, to patients without a medical prescription from a physician. In this study, it was found that more than 55% of pharmacists involved in the survey dispensed this important antibiotic without receiving a medical prescription from the doctor (Fig. 3.3). This result is also obtained in many previous studies about the dispensing practice of antibiotics among pharmacists in community pharmacies in Sudan [15,16]. In fact, the irrational AZA dispensing from the community's pharmacist and relative lower price of AZA (Fig. 3.4) might lead to high overall antibiotic consumption, which my lead to the development of antimicrobial resistance to this antibiotic in the future. To overcome these problems, community pharmacists should be well advised for rational dispensing practices of this important antibiotic.

A drug shortage can be defined as a gap in the supply of drugs that means it is impossible to meet current or anticipated patient demand. Drug shortages can have important economic and clinical impacts at all levels of the health care system, including patients, pharmacists, clinicians, the pharmaceutical industry, and policy makers. Based on the results of this study, there is a shortage of AZA antibiotics on the pharmaceutical market in the state of Khartoum. This shortage can be resolved by increasing local production of AZA antibiotics and creating new pharmaceutical industries to increase the overall production of the antibiotic. However, it is costly for a developing nation like Sudan. An easier alternative solution is to educate antibiotic users

(doctors, pharmacists and patients) about the danger to their health from the irrational use of antibiotics in general and AZA antibiotics in particular. In essence, it requires the participation of physicians, hospital and community pharmacists, patients, and drug regulators [17].

This study was primarily aimed at estimating the supply and demand for AZA antibiotics and projecting its demand in Khartoum state. It has the limitation of what it has analyzed the actual supply and the actual demand for AZA in Khartoum state only but does not represent overall the whole of Sudan. It does not reflect the supply and demand for AZA antibiotics elsewhere in Sudan. Therefore, this study strongly recommend carrying out a similar study taking into account the supply/demand of AZA antibiotics across the states of Sudan.

Conclusions

In this study, it is estimated the real demand for AZA antibiotic in 2022 in Khartoum State, Sudan and project

demand of this antibiotic for the next 10 years using drug-consumption data approach. This study found that there is a gap of AZA antibiotic between the real demand and actual supply that should be filled. This study can be used as a guide to estimate the actual supply and the real demand for AZA antibiotic and to predict its real demand for the future.

Acknowledgments

Conflict of interest

The authors declare no conflict of interest in this study.

References

(1) Dash S, Shakyawar S, Sharma M, Kaushik S. Big data in healthcare: Management, analysis and future prospects. Journal of Big Data. 2019;6:54-66.

(2) Mbonyinshuti F, Takarinda K, Ade S, Manzi M, Iradukunda P, Kabatende J, Habiyaremye T, Kayumba P. Evaluating

the availability of essential drugs for hypertension, diabetes and asthma in rural Rwanda, 2018. Public Health Action. 2021;11:5–11.

(3) Mukundiyukuri J, Irakiza J, Nyirahabimana N, Ng'Anga L, Park P, Ngoga G, El-Khatib Z, Nditunze L, Dusengeyezu E, Rusangwa C. Availability, Costs and Stock-Outs of Essential NCD Drugs in Three Rural Rwandan Districts. Annals of Global Health. 2020; 86:123-29.

(4) Omer AM, Ali G. Assessment of the Substandard Drugs in Developing Countries: The Impact of the Pharmaceutical Regulations on the Quality of Medicines on the Sudanese Market Importers' Perspective. ARC Journal of Pharmaceutical Sciences. 2014; 1: 171-81.

(5) Elawad M, Abdelkarim MA, Murtada AO, Muhammad N. Market Survey and Assessment of the Demand for Amoxicillin 500 mg Capsules in Sudan. Life & Science. 2021;2(1):1-4.

(6) Abdeen MO. Some Aspects of Medicine Distribution in Sudan. Journal of Pharmacy and Pharmaceutics. 2018; 5(2): 61-79.

(7) Murtada AO, Abdelkarim MA. Design and evaluation of cost effective conventional tablets from *Monechma ciliatum* seeds extract. International Journal of Pharmaceutical Science Research. 2013; 4(2):631-40.

(8) Shinji K,Teruhiko K,Koki M,Yukako I, Toshiyuki S. Pharmacokinetics of Macrolide Antibiotics and Transport into the Interstitial Fluid: Comparison among Erythromycin, Clarithromycin, and Azithromycin. Antibiotics. 2020; 9(4):199-205.

(9) Togami K, Chono S, Morimoto K. Distribution characteristics of clarithromycin and azithromycin, macrolide antimicrobial agents used for treatment of respiratory infections, in lung epithelial lining fluid and alveolar macrophages. Biopharmaceutics & Drug Disposition. 2011; 32:389-97.

(10) Kheder SI, Ali HM. Medicine prices, availability, affordability and price components in Sudan. Sudanese Journal of Public Health. 2014; 5(2): 29-31.

(11) Elamin EI, Ibrahim MIM, Yousif M. Availability of essential medicines in Sudan.

Sudanese Journal of Public Health. 20104; 5: 32-37.

(12) Measuring medicines prices, availability, affordability and price coponents 2nd edition." 2008. World Health Organization and Health Action International, Geneva, Switzerland.

(13) Abdeen MO. Some Aspects of Medicine Distribution in Sudan. Journal of Pharmacy and Pharmaceutics. 5(2): 61-79.

(14) Elhada AH, Eltayeb IB, Mudawi MM, Pattern of self-medication with antibiotics in Khartoum State, Sudan, World Journal of Pharmaceutical Research. 2014; 3(5):678–92.

(15) Osman K, Reem A, Ahd Alaaeldin H, Mohammed E, Mugahid A, Randa A, Rayan I, Tagwa F. Perception and practice of self-medication with antibiotics among medical students in Sudanese universities: A cross-sectional study. Plos One. 2022;26:1-15.

(16) Azhari E, Habab A, Walaa S, Eman A, Lina A, Emad M. Irrational Use of Three Antibiotics in Khartoum, Sudan: A Cross-Sectional Study. Novel Approach in Drug Design and Development. 2022; 6(2):555685.

(17) Murtada AO. Cosmomedical potentials of black mahlab seeds growing in Sudan. International Journal of Research and Development in Pharmacy and Life Sciences. 2013;2(4):519-26.