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The Impact of the Health Transformation Plan on Injectable Antibiotic Prescription Patterns: A Case Study of Bu-Ali Hospital

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ABSTRACT

Background: Health systems must continuously adapt and undergo reforms in both structure and function to effectively meet the evolving needs of society and respond to changing conditions. Due to the importance of the role of drug studies in rationalizing the pattern of drug use, the current study was based on the anatomical therapeutic chemical (ATC) classification system and the defined daily dose (DDD) developed by World Health Organization (WHO).
Methods: This study is a retrospective, cross-sectional, descriptive-analytical analysis of injectable antibiotic prescriptions at Bu-Ali Hospital from 2012 to 2017. Data were extracted from the Hospital Information System (HIS), focusing on injectable antibiotics administered and consumed during hospital stays. The Kolmogorov-Smirnov test was used to assess data normality, and the paired t-test was applied to compare the periods before and after the implementation of the HTP. The Wilcoxon signed-rank test was also used for paired group comparisons.
Results: Following the implementation of the HTP, all investigated indicators include total number, DDD and cost showed a significant increase compared to the pre-HTP period. Only the cost per capita (p-value=0.712) and amount per capita (p-value =0.182) of total injectable antibiotics decreased post-HTP, though this change was not statistically significant.
Conclusion: The HTP in Iran significantly influenced antibiotic prescription patterns at Bu-Ali Hospital, leading to increased usage of injectable antibiotics and DDD. These changes improved access to potent antibiotics, but continued monitoring is necessary to ensure responsible usage and prevent antimicrobial resistance.

Keywords: Healthcare policy, Out-of-pocket payments, Healthcare reform, Resource allocation

Introduction

Health systems of countries in the world require modifications to comply with global trends, hence it can be observed that health systems are being transformed and reformed in various countries (1–3). A comprehensive plan for health transformation is vital for health systems that may desire to achieve an effective service delivery mechanism as well as good patient outcomes. It also ensures that health services offered are more responsive to the emerging health care needs, incorporates more advanced technologies as well as maintain evidence-based practices in the health sector (4). Besides, proper transformation programs assure equal resource allocation and delivery of quality care while eliminating health disparities (5). Adopting a transformation plan that health systems can quickly adapt to population health trends, manage chronic diseases, and increase sustainability in the patient-worker system is necessary (6). Such a transformation plan is vital in achieving long-term effects to health service provision and patient satisfaction (7).

As in other countries, Iran's ministry of health and medical education (MOHME) designed a comprehensive plan for the transformation of the country's health system in order to achieve the vision of 2025, which was implemented on May 5, 2014 (8,9). The Health Transformation Plan (HTP) in Iran focuses on improving financial protection for patients, promoting equitable access to quality healthcare for all members of society, and enhancing health system efficiency to help achieve universal health coverage (10). The proper functioning of hospitals plays an important role in the recovery and return of patients to society, for example just as the smallest error in the prescriptions will lead to many problems (11,12).

The Role of Antibiotics and Challenges of Resistance

In the context of health transformation, addressing specific challenges like the proper use of antibiotics is essential. Nowadays, antibiotics are one of the most widely used class of drugs in hospital globally; therefore, they include a huge part of the drug treatment costs of hospitalized patients (13). Irrational prescription of antibiotics in hospital has been linked to higher microbial resistance and higher morbidity and mortality rates of patients (14). Irrational prescription and use of antibiotics causes resistance in bacteria and the emergence of new resistant species, which causes irreparable financial and clinical losses to the healthcare system (15). it's estimated that between 22% and 73% of treatments for hospital-acquired infections are inappropriate. Indeed, it is even more significant in low-income countries, with 44% to 97% of prescriptions being misused, unnecessary or wrong. This results in a rise in bacterial resistance and poor health outcomes (16). Spread of microbial resistance in community requires more prolonged diagnosis and treatment. Due to this cause, in the 21st century, we are about to face broad health and treatment threats (17).

Antimicrobial resistance (AMR) had an estimated 4.95 million deaths in 2019, 1.27 million of which were directly due to bacterial AMR. The death rate varied from 27.3 per 100,000 in western sub-Saharan Africa to 6.5 per 100,000 in Australasia. More than 1.5 million of the deaths associated with AMR were attributed to lower respiratory infections (18). Estimations indicate that by 2050, AMR will lead to 10 million deaths each year and will have cumulatively cost the world economy up to $100 trillion. Using these projections from the OECD model, resistant infections will have led to 2.4 million deaths in the same countries (in addition to Canada, Mexico, and Australia) by the same year, with approximately 30,000 deaths per year from the United States (19,20).

Health system transformation plans and antibiotics prescription

Governments are adopting policy strategies to fight the challenge of antibiotic resistance as one of the most serious public health challenges. These strategies involve promotion in appropriate use of antibiotics by undertaking stewardship programs, developing antibiotic guidelines, and other strategies. All these efforts are being made to reserve the effectiveness of antibiotics, so they should remain a strong intervention against infectious diseases (21,22). Furthermore, combating antibiotic resistance requires a systematic

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approach, which includes governments incorporating health system transformation plans to address this challenge comprehensively and sustainably, ensuring the rational use of antibiotics.

Implemented HTP significantly affected Iran's healthcare system, particularly how antibiotics were prescribed. After implementation of the HTP in Iran, concerns have arisen regarding the potential overprescription of antibiotics, a longstanding issue in the country's healthcare system.

This study aims to investigate the effects of the HTP on the utilization of injectable antibiotics in Iran's healthcare system, using Bu-Ali Hospital as a case study. Specifically, it examines whether the reduction in patient costs under the HTP has led to an unintended increase in antibiotic consumption. By analyzing trends in antibiotic usage, costs, and defined daily dose (DDD) before and after the implementation of the HTP, the research seeks to identify potential shifts in prescribing patterns. The findings will provide critical insights into the broader consequences of healthcare reforms on prescribing practices and antimicrobial resistance, while also evaluating the HTP's effectiveness in promoting rational antibiotic use and improving healthcare delivery.

Methods

This study was designed as a descriptive, cross-sectional, and retrospective study, utilizing data from 2012 to 2017 to assess the impact of the HTP on the use of injectable antibiotics at Bu-Ali Hospital by comparing pre- and post-implementation periods of the HTP; it is important to note that due to the unavailability of data for the years 2010 and 2011, all analyses were conducted using data from 2012 to 2017.

Data Collection and Classification

Data collection was conducted comprehensively, utilizing available sources to ensure accuracy and completeness. The study focused on documenting records of injectable antibiotics prescribed and administered during patient stays across different wards at Bu-Ali Hospital. These records were retrieved from the hospital's patient file system, which is integrated into the HIS. Besides, yearly sales data for 2012-2017 for the Bu-Ali Hospital pharmacy have been gathered using HIS and categorized based on hospital wards.

The study included 44 different dosage forms from different antibiotic groups. A detailed list of the injectable antibiotics studied, along with their DDD and Anatomical Therapeutic Chemical (ATC) classification codes, is provided in Supplementary Table 1.

To thoroughly assess consumption patterns and costs, data on injectable antibiotics were first isolated and then categorized into general and minor groups based on ATC codes. The data were divided into two distinct periods: before the HTP implementation (2012-2013) and after its implementation (2014-2015). This allowed for an analysis of the HTP's impact on antibiotic usage and associated metrics.

Result and Discussion

The data were analyzed using SPSS version 26. Initially, descriptive statistics, including means and standard deviations, were calculated for the two periods, before and after the implementation of the transformation plan.

The Kolmogorov-Smirnov test was used to check the normality of data distribution, while the Wilcoxon signed-rank test compared variables before and after the HTP implementation. Given that the study focused on specific antibiotic classes within each ward, leading to potential intra-group correlations, multilevel mixed models were applied to account for the stratified effects of pharmaceutical departments and pharmaceutical groups.

Each of the following parameters was analyzed separately for different pharmaceutical classes and hospital wards: 1) DDD of injectable antibiotics 2) Number of injectable antibiotics 3) Number of patients 4) Cost per capita in Iranian Rial (IRR) 5) Amount per capita. The DDD, based on use in the World Health Organization (WHO), is an approximate daily average dose needed for a drug when it is prescribed for its main use in adults (23).

Throughout the 2012-2017 study period in Bu-Ali hospital, admissions in various wards increased during that period. In 2012, 3,094 admissions took place in the hospital, but admissions increased remarkably in 2017 to 22,025. There was a high rise in admissions in the Internal ward, with admissions growing from 988 in 2012 to 10,985 in 2017, suggesting growing demand for medical care in that ward. There was high growth in admissions in the

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Surgery ward, with admissions growing over two times, from 1,205 in 2012 to 7,984 in 2017, suggesting overall expansion in providing care.
Other wards, such as Pediatrics and ICU (Intensive Care Unit), displayed varying trends inpatient admissions. For instance, the Pediatric ward peaked in 2013 with 1,311 patients, followed by a stabilization to around 600-700 patients in the subsequent years. Meanwhile, the ICU showed a consistent rise in admissions, indicating an increasing need for critical care services, potentially linked to an aging population or more complex cases being treated at the hospital. Overall, the patient demographics underscore the profound effect of the HTP on hospital utilization, with more individuals accessing and benefiting from the healthcare services at Bu-Ali hospital. Data from Table 1 shows the number of patients by ward from 2012 to 2017. The total number of patients increased significantly over this period, with notable rises in the internal and surgery wards.

Table 1. Total number of patients by ward from 2012 to 2017. Abbreviation: ICU, intensive care unit. CCU, critical care unit

Ward \ Year	2012	2013	2014	2015	2016	2017
Pediatrics	367	1311	725	698	615	337
Internal	988	4169	6559	7825	7464	10985
Obstetrics	29	391	505	82	454	355
Surgery	1205	4361	5563	7830	6915	7984
Intensive care (ICU and CCU)	505	2082	2056	2734	2660	2364
Total	3094	12314	15408	19169	18108	22025

Impact of HTP on Injectable Antibiotic Prescription Patterns

Results, as seen in Table 2, reveal that use of injectable antibiotics at Bu-Ali Hospital rose in an exponential manner between 2012 and 2017. Total antibiotics rose from 13,814 to 71,115, and DDD rose from 4,332.3 to 20,745.8. Cost of total antibiotics rose in a positive direction, with an increased cost in an upward direction, starting with 4,668,600 in 2012 and rising to 9,691,000 in 2017. Cost per capita, even with fluctuations, with a high in 1,320,558.3 in 2016 and a fall to 1,159,174.9 in 2017, rose steadily, with increased availability and use of antibiotics in these years. All these observations reveal a striking change in prescription and consumption behavior, and a sign of success in accessing care and reduced financial burden to patients through HTP intervention.

Table 2. Trends in Injectable Antibiotic Usage (2012–2017)

Variable	2012	2013	2014	2015	2016	2017
Total Number	13,814	48,921	58,143	67,386	62,959	71,115
DDD	4,332.3	13,918.8	18,004.1	17,882.4	18,175.2	20,745.8
Cost (IRR)	4,668,600	6,702,900	8,173,000	7,061,700	7,273,700	9,691,000
Cost per Capita (IRR)	835,968.3	742,615.1	1,087,511.9	597,097.6	1,320,558.3	1,159,174.9
Amount per Capita	374	437	469.4	541.7	451.5	589.1

Trends in Injectable Antibiotic Consumption by Category

The use of Penicillins saw a significant upward trend across all wards, particularly in the Pediatric ward, where consumption surged from 265 units in 2012 to a peak of 1,101 units in 2015, before tapering off to 486 units by 2017. This initial increase suggests a broader application of Penicillins in pediatric care during those years, possibly as a first-line treatment for various infections. However, the drop below could mark a transition towards alternative classes of antibiotics, or a lesser use of Penicillins in consideration of growing concerns about antibiotic resistance. In the Internal ward, a similar trend, consumption increased from 46 units in 2012 to 451 in 2015, then lowered to 278 in 2017. In the ICU ward, consumption

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peaked in 2014 at 519, but lowered to 377 in 2017, possibly in consideration of a transition towards even stronger antibiotics in critical care environments.

Cephalosporin usage grew immensely in all wards, bearing witness to its increased use in treating a range of infections. In the Pediatric ward, consumption grew enormously from 279 in 2012 to 1,294 in 2013, then decreased to 594 in 2017. That bears witness to a high demand for Cephalosporins in treating kids, possibly for its effectiveness in a range of infections and its efficacy in overcoming resistant strains of bacteria. In the most considerable rise, Cephalosporin use in the Internal ward experienced a high demand, with its use spiking enormously between 1,844 in 2012 and 5,449 in 2017. Perhaps, its high demand in such a high rise could be an indication of an increased patient base with complex infections that require a range of antibiotics. In the Surgery ward, Cephalosporin consumption grew steadily, with a high of 14,135 in 2015, bearing witness to its use in preventing and treating postoperative infection.

Carbapenem use, with its high effectiveness in multi-drug resistant bacterial infection, rose immensely too. In the Internal ward, use rose from 704 units in 2012 to 6,268 units in 2017, indicative of a heightened use of such powerful antibiotics in controlling critical infection cases. In the ICU ward, a similar rise could be noticed, with use growing from 942 units in 2012 to 3,735 units in 2017, indicative of a rise in use of such powerful antibiotics in critical cases, in which resistant infection is a larger concern. In contrast, in the Pediatric ward, negligible use of Carbapenems could be noticed, with a high of only 173 units in 2013, indicative of a guarded use of such powerful antibiotics in children.

Aminoglycoside utilization varied between wards, with the Pediatric ward peaking at 809 units in 2013, then falling to 143 units in 2017. This fall most likely mirrors a switch to safer or more effective agents, given the known risks of nephrotoxicity and ototoxicity of Aminoglycosides. In the Internal ward, their utilization peaked at 651 units in 2015, mirroring their continued utility in the treatment of severe infection, particularly in the elderly. Table 3 shows the total amount of antibiotics consumed by different classes of antibiotics according to the hospital wards for the years 2012 to 2017.

Table3. The total antibiotics consumption during the years 2012 to 2017 by categories of antibiotics according to hospital wards

Group	Ward	2012	2013	2014	2015	2016	2017
Penicillins	Pediatrics	265	937	983	1101	814	486
	Internal	46	348	722	451	170	278
	Obstetrics	0	51	82	68	86	106
	Surgery	197	441	500	395	457	448
	ICU	91	105	519	223	57	377
Total		599	1882	2806	2238	1584	1695
Cephalosporins	Pediatrics	279	1294	787	1077	1221	594
	Internal	1844	7847	8358	6637	6485	5449
	Obstetrics	39	556	751	663	563	373
	Surgery	3231	9937	11490	14135	10972	7000
	ICU	689	2231	1372	2131	1882	1309
Total		6082	21865	22758	24643	21123	14725
Carbapenems	Pediatrics	67	173	21	1	0	165
	Internal	704	6072	7711	9799	9118	6268
	Obstetrics	0	0	0	0	4	0
	Surgery	279	1487	2794	3570	3816	3664
	ICU	942	4769	4614	6360	6807	3735
Total		1992	12501	15140	19730	19745	13832
Aminoglycosides	Pediatrics	358	809	738	729	520	143
	Internal	231	517	594	651	462	316
	Obstetrics	3	53	45	37	0	18
	Surgery	515	342	736	1397	1199	1355
	ICU	135	190	276	404	269	306

Total		1242	1911	2389	3218	2450	2138
Fluoroquinolones	Pediatrics	0	0	0	0	0	1
	Internal	0	0	0	0	0	9237
	Obstetrics	0	0	0	0	0	0
	Surgery	0	0	0	0	0	2845
	ICU	0	0	0	0	0	2186
Total		0	0	0	0	0	14269
Sulfonamides	Pediatrics	0	0	0	0	0	0
	Internal	0	0	0	0	0	115
	Obstetrics	0	0	0	0	0	0
	Surgery	0	0	0	0	0	156
	ICU	0	0	0	0	0	166
Total		0	0	0	0	0	437
other	Pediatrics	166	472	164	154	76	113
	Internal	1592	4835	7763	7709	8009	9442
	Obstetrics	0	8	7	3	40	6
	Surgery	1069	2686	4121	6080	6243	10323
	ICU	1072	2761	2995	3611	3689	4135
Total		3899	10762	15050	17557	18057	24019

DDD Trends and Utilization Patterns

Penicillin usage varied significantly across hospital wards, with notable changes observed in the ICU and Internal wards. For Pediatrics, DDD for Penicillins was at its peak at 102 in 2015 and then reduced to 41 in 2017, with a move towards alternate antibiotics and even towards individual drugs. In ICU, DDD rose in a sharp direction, beginning at 15 in 2012 and 156 in 2014, with fluctuations in between, with a high at 114 in 2017. This suggests that while penicillins remained crucial in critical care, their usage was adjusted based on clinical needs and resistance trends. The Internal ward experienced a peak DDD of 341 in 2014, followed by a reduction to 100 in 2017, reflecting a dynamic approach to infection management in this ward.

Cephalosporins showed consistently high DDD values, especially in the Surgery and Internal wards, underscoring their central role in treating infections. The Surgery ward's DDD climbed from 1,274 in 2012 to a peak of 4,645 in 2014, with a slight decrease to 3,259 by 2017, proposing that while Cephalosporins were vital for surgical infection control, their usage was moderated in later years, possibly due to the adoption of alternative strategies. The Internal ward also saw a high DDD, peaking at 3,601 in 2014 before declining to 2,385 in 2017, highlighting their widespread use, particularly for older patients or those with multiple health issues.

Carbapenem usage surged, particularly in the ICU and Internal wards, reflecting their importance in managing multi-drug-resistant infections. The ICU's DDD increased from 258 in 2012 to a peak of 1,966 in 2016, indicating a growing reliance on these powerful antibiotics for severe cases. Similarly, the Internal ward's DDD rose from 183 in 2012 to 2,724 in 2015 before falling to 1,006 in 2017, suggesting that while Carbapenems became more critical over time, there was an effort to reduce their use later, likely to prevent resistance.

Aminoglycosides, though less frequently used than other antibiotics, showed some variability in usage. In Pediatrics, the DDD peaked at 88 in 2013 but dropped to 31 in 2017, likely due to concerns about toxicity. In the ICU, the DDD steadily increased, reaching 177 in 2015, indicating their continued relevance for specific infections, particularly in critically ill patients. The Internal ward also used Aminoglycosides moderately, with a peak DDD of 257 in 2015, reflecting their ongoing role in treating severe infections despite associated risks.

Distribution of overall DDD of antibiotics between 2012 to 2017 years between classes of antibiotics in terms of types of hospitals' wards is seen in Table 4.

Table 3. The total DDD of antibiotics during the years 2012 to 2017 by antibacterial categories according to hospital wards

Group	Wards	2012	2013	2014	2015	2016	2017
Penicillins	Pediatrics	32	75	93	102	76	41
	ICU	15	20	156	55	14	114
	Obstetrics	0	9	0	11	14	17
	Surgery	36	74	134	64	95	109
	Internal	10	56	341	159	47	100
Cephalosporins	Pediatrics	114	429	189	289	350	181
	ICU	313	1015	953	934	839	507
	Obstetrics	13	186	250	222	188	121
	Surgery	1274	2482	4645	3397	4338	3259
	Internal	868	3480	3601	2883	2972	2385
Carbapenems	Pediatrics	12	58	4	0	0	1
	ICU	258	1370	1337	1848	1966	958
	Obstetrics	0	0	0	0	1	0
	Surgery	73	413	779	946	1116	1038
	Internal	183	1714	2189	2724	2084	1006
Aminoglycosides	Pediatrics	59	88	74	74	50	31
	ICU	57	80	114	177	125	143
	Obstetrics	1	18	14	12	0	16
	Surgery	180	148	267	216	156	455
	Internal	105	186	220	257	176	115
Fluoroquinolones	Pediatrics	0	0	0	0	0	1
	ICU	0	0	0	0	0	920
	Obstetrics	0	0	0	0	0	0
	Surgery	0	0	0	0	0	811
	Internal	0	0	0	0	0	2988
Sulfonamides	Pediatrics	0	0	0	0	0	0
	ICU	0	0	0	0	0	42
	Obstetrics	0	0	0	0	0	0
	Surgery	0	0	0	0	0	39
	Internal	0	0	0	0	0	29
other	Pediatrics	42	113	35	37	19	34
	ICU	206	574	666	798	823	980
	Obstetrics	0	1	1	1	7	2
	Surgery	199	434	436	1150	1142	2279
	Internal	286	897	1508	1529	1579	2027

Economic Impact: Cost Analysis of Injectable Antibiotics

Table 5 shows the total number, total DDD, cost per capita in Rials, and amount per capita for each category of injectable antibiotics from 2012 to 2017. The data indicates a general trend of increasing costs and usage across all categories, with notable peaks in specific years for different antibiotics.

Table 4. Total number, total DDD, cost, cost per capita and amount per capita for each group of injectable antibiotics from 2012 to 2017

Group	Variable	Year					
		2012	2013	2014	2015	2016	2017
Penicillins	Count	599	1882	2806	2238	1584	1695
	DDD	92.8	233.1	723.5	390.3	245.2	381.3
	Cost (IRR)	121200	416000	1091000	707500	879000	1357000
	Cost per capita (IRR)	47070.2	180997.1	254598.2	198157.9	339911.3	392279.8
	Amount per capita	76.5	85.7	115.1	157.8	113.8	154.3
Cephalosporins	Count	6082	21865	22758	24643	21123	14725
	DDD	2581.7	7591.5	9638.0	7724.1	8685.6	6452.0
	Cost (IRR)	712500	1518000	1263000	1456500	1587000	2357000
	Cost per capita (IRR)	247601.3	384203.2	314344.7	264783.8	499475.3	484015.2
	Amount per capita	105.2	143.9	116.9	177.6	140.2	128.5
Carbapenems	Count	1992	12501	15140	19730	19745	13832
	DDD	524.6	3554.9	4308.0	5518.5	5166.8	3002.8
	Cost (IRR)	3457500	4105000	5125000	4237000	4105000	2732200
	Cost per capita (IRR)	508813.3	102729.7	452147.2	93376.6	400305.7	61815.7
	Amount per capita	62.0	68.2	87.5	79.5	71.8	77.2
Aminoglycosides	Count	1242	1911	2389	3218	2450	2138
	DDD	401.5	519.6	689.9	735.1	507.6	758.5
	Cost (IRR)	105400	176200	200000	166700	169700	521600
	Cost per capita (IRR)	14151.6	33590.0	50138.3	25417.2	48676.1	104135.7
	Amount per capita	42.9	60.4	66.6	51.7	49.9	56.8
Fluoroquinolones	Count	0	0	0	0	0	14269
	DDD	0.0	0.0	0.0	0.0	0.0	4719.9
	Cost (IRR)	0	0	0	0	0	1250200
	Cost per capita (IRR)	0.0	0.0	0.0	0.0	0.0	30947.1
	Amount per capita	0.0	0.0	0.0	0.0	0.0	34.9
Sulfonamides	Count	0	0	0	0	0	437
	DDD	0.0	0.0	0.0	0.0	0.0	109.2
	Cost (IRR)	0	0	0	0	0	96000
	Cost per capita (IRR)	0.0	0.0	0.0	0.0	0.0	24361.9
	Amount per capita	0.0	0.0	0.0	0.0	0.0	38.7
Other	Count	3899	10762	15050	17557	18057	24019
	DDD	731.7	2019.7	2644.6	3514.4	3570.0	5322.1
	Cost (IRR)	272000	487700	494000	494000	533000	1377000
	Cost per capita (IRR)	18331.9	41095.0	16283.5	15362.2	32189.9	61619.5
	Amount per capita	87.4	78.9	83.3	75.2	75.9	98.7

According to the table 5, we observed various trend in cost of various group of injectable antibiotics. Generally, penicillin price rose, with a steep rise in 2014 and 2017. Price of cephalosporins rose in 2015 and 2016, and that of carbapenems rose between 2014 and 2017. Contrarily, price of aminoglycosides fell in 2015 and 2016 compared to preceding and succeeding years. The two categories of fluoroquinolones and sulfonamides were used only in 2017.

Comparative Statistical Analysis Before and After HTP

Using the paired t-test, we have compared the two periods before and after the transformation plan. The implementation of the HTP has been effective on all the studied indicators. Only in cost per capita (p-value=0.712) and amount per capita (p-value=0.182) the difference between the averages before and after it was not statistically significant from the implementation of the plan. But for the rest of the indicators, this difference was significant (p-value<0.05). The mean cost of injectable antibiotics was increased in the two periods before and after the implementation of the HTP for each pharmaceutical classes. After taking into account the classes including inpatient cares and the type of drug class, the difference in the total drug cost in the two periods before and after the transformation plan was statistically significant (p-value< 0.01). Table 6 shows the mean and standard deviation of the investigated indicators of Bu-Ali hospital in Tehran and their comparison in the two periods before and after the transformation plan of the health system.

Table 5. Mean and standard deviation of performance indicators of Tehran Bu-Ali hospital and their comparison in two periods before and after the health system transformation plan. Abbreviation: DDD, Defined Daily Dose. HTP, Health Transformation Plan.

Metric (Average)	Before HTP Implementation (Mean ± SD)	After HTP Implementation (Mean ± SD)	Mean Difference	p-Value
Total Number	137.7 ± 34.1	465 ± 120.8	327.3	<0.001
DDD	49.8 ± 10.7	159.7 ± 34.4	109.9	<0.001
Cost (IRR)	43,056.9 ± 11,584.6	47,990.5 ± 16,632.5	4933.6	0.002
Cost per Capita (IRR)	10,986.1 ± 2,064.1	6,375.4 ± 1,833.6	-4610.7	0.712
Amount per Capita	2.3 ± 0.9	0.1 ± 0.01	-2.2	0.182

Conclusion

The findings of this study reveal that the implementation of the HTP in Iran significantly influenced antibiotic prescription patterns at Bu-Ali Hospital, leading to increased consumption of injectable antibiotics, as reflected in the rise in total usage, DDD, and costs, particularly high-potency drugs like carbapenems and cephalosporins. This trend aligns with the HTP's goal of reducing out-of-pocket expenses and improving healthcare accessibility, which likely contributed to higher antibiotic use. However, the shift toward more expensive and potent antibiotics raises concerns about antibiotic resistance and the long-term sustainability of such practices, underscoring the need for robust antibiotic stewardship programs. Post-HTP implementation, the highest antibiotic consumption was observed in carbapenems, cephalosporins, and other antibacterial groups, especially in internal, surgery, and ICU wards. The study noted a rise in the use of mid-range priced antibiotics (50,000 to 200,000 Rials), while the introduction of high-cost antibiotics (over 200,000 Rials) coincided with the HTP. Although price stability since 2012 rules out inflation as a factor, the increased use of costly drugs has driven up overall healthcare expenses. This highlights the dual impact of the HTP: improved access to effective treatments but also heightened financial and resistance-related challenges. The HTP's success in reducing out-of-pocket costs has likely encouraged greater healthcare utilization, including antibiotic use. However, the increased reliance on high-potency antibiotics, while beneficial in the short term, may exacerbate antibiotic resistance. Future studies should investigate the correlation between antibiotic consumption and resistance patterns, particularly in high-use wards, to assess medical justification and cost-effectiveness. Continuous monitoring and evaluation of the HTP's impact are crucial to balancing improved healthcare access with sustainable antibiotic use and resistance prevention.

Among the limitations of this study, given the extensive time period under investigation, is the possibility of minor errors in the data extracted from the hospital pharmacy's HIS system. However, due to the lengthy duration of the study, these errors are considered negligible. Additionally, given the systematic analysis of data trends over a 6-year period, these limitations are unlikely to significantly impact the results. In conclusion, the HTP in Iran significantly increased the prescription and consumption of injectable antibiotics at Bu-Ali Hospital, as evidenced by rises in total usage, DDD, and costs. While the program exposed more patients to more intense antibiotics and reduced patients' out-of-pocket costs, it also changed prescribing patterns to more costly antibiotics. The findings reaffirm that there is a need to continue surveillance to sustain responsible antibiotic use to prevent potential threats of resistance to antimicrobials, a need to strike a balance between healthcare accessibility and responsible antibiotic stewardship.

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Conflict of Interest

None

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Ethical Considerations

In this study, since aggregated data were used and patient-specific information was not processed individually, the principles of data confidentiality and privacy were fully upheld. Additionally, the necessary permissions for accessing and utilizing hospital data were obtained from the relevant authorities to ensure that the research conducted within an appropriate ethical and legal framework. This study is approved under the ethical approval code of IR.IAU.PS.REC.1398.157 by the Research Ethics Committees of Islamic Azad Tehran Medical Sciences University - Pharmacy and Pharmaceutical Branches Faculty available at https://ethics.research.ac.ir/IndexEn.php.

Authors' contributions

All of the authors have contributed to this work, including its conception, design, conduct, analysis, and critical review of the manuscript. They have all reviewed and approved the final version for publication. Additionally, the authors have mutually agreed on the journal selection and take full responsibility for the integrity and accuracy of the work.

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