

Original article

Factors influencing microbial diagnostic testing for infectious diseases in Korea: a nationwide retrospective cohort study

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Abstract

Background: Diagnostic tests are essential for accurate disease identification and monitoring treatment responses. This study aimed to assess the factors influencing the requests for microbial diagnostic tests in patients with various infections.

Methods: Using tailored data from the National Health Insurance Big Data, we examined the usage patterns of microbiological tests among patients with pulmonary tuberculosis (TB) and major bacterial infections between 2020 and 2022, excluding overlapping and complex infections (n = 8,268,992). The types of bacterial infections included pneumonia, sepsis, urinary tract infections, and soft tissue infections, for which bacterial culture and antimicrobial susceptibility tests were performed. For pulmonary TB cases, acid-fast bacillus smears, mycobacterial cultures, and molecular diagnostic tests were performed. Multivariate analysis was used to identify the factors influencing the prescription of microbiological diagnostic tests, considering variables such as age, sex, Charlson comorbidity index, underlying disease, type of medical institution, residential area, insurance quintile, and disability status.

Results: Requests for TB-related and bacterial infection-related tests varied according to multiple factors, including sex, age, insurance quintile, residential area, presence or absence of disability, disease severity, type of medical institution admission, chemotherapy, steroid use, comorbid conditions, and underlying diseases.

Conclusions: This study provides a rare analysis of large-scale national data on various factors affecting test prescriptions, which could provide useful data for improving policies for appropriate test prescriptions.

Keywords: Big data, Bacterial infections, Communicable diseases, Pulmonary tuberculosis, Routine diagnostic tests



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Introduction

Background

Pulmonary tuberculosis (TB), pneumonia, sepsis, urinary tract infection (UTI), and soft tissue infection (STI) significantly affect public health and can lead to mortality, morbidity, and disability, thereby lowering overall societal health standards.

Pulmonary TB remains a critical public health concern, accounting for over 10 million cases and 1.6 million deaths worldwide by 2021 [1]. TB-related diagnostic practices include acid-fast bacillus (AFB)

smears, mycobacterial cultures, and molecular testing [2]. Bacterial culture and antimicrobial susceptibility testing (AST) are fundamental diagnostic procedures for suspected infectious diseases [3].

Objectives

This study aimed to evaluate the current patterns of microbiological test requests for diagnosing pulmonary TB and major bacterial infections to determine the factors influencing these test prescriptions.

Materials and methods

Study design

This nationwide, retrospective cohort study utilized data from the Korean National Health Insurance (NHI) Customized Data Service.

Setting

This nationwide population-based retrospective study used data from the National Healthcare System of the Republic of Korea. The study period included all patient encounters and diagnostic test requests recorded between January 2020 and December 2022. This setting encompasses all types of medical institutions covered by the national insurance program, including senior general hospitals, general hospitals, clinics, and nursing hospitals.

Study population

The study population included all patients within the NHI system who were diagnosed with one of the five infectious diseases: pulmonary TB, pneumonia, sepsis, UTI, or STI. The patients were identified based on their corresponding diagnostic codes from the Korean Standard Classification of Diseases (Supplementary Table 1 in the online-only Data Supplement). The types of bacterial infections were selected according to the Centers for Disease Control and Prevention/National Healthcare Safety Network surveillance definitions for specific types of infections [4]. For hospitalized patients, repeated admissions within the same hospitalization period were considered as single episodes.

To eliminate the influence of duplicate cases, only the first occurrence in each patient during the study period was included. Patients with complex infections, defined as those with more than two infectious diseases, were excluded, and only those with a single infection (one diagnosis) were analyzed.

Data sources

The primary data source for this study was the NHI Customized Data Service. This comprehensive administrative database contains nationwide claims data for a vast majority of the South Korean population.

Variables/measurement

The analysis focused on a primary outcome variable (the prescription of a microbial diagnostic test). The predictor variables, or factors assessed for their influence on test ordering, included a range of demographic, clinical, and social characteristics.

Diagnostic tests: the study assessed the prescription patterns of AFB smear, mycobacterium culture, and real-time polymerase chain reaction (molecular diagnostic tests) for mycobacteria in patients suspected of having pulmonary TB by referencing the NHI diagnostic codes (Supplementary Table 2 in the online-only Data Supplement). In patients suspected of having pneumonia, sepsis, UTI, or STI, the utilization of bacterial cultures and AST was reviewed (Supplementary Table 2 in the online-only Data Supplement). Monthly trends in test requests were presented and standardized per one million patients.

Patient demographics: age, sex, residential area, and disability status. Age groups were defined as 0-19 years at the time of diagnosis, with subsequent ages classified into 10-year intervals. Residential areas were determined by resident registration and were classified into eight metropolitan cities and nine administrative districts. Additionally, residential locations were analyzed by region, with three categories defined: region 1 (metropolitan areas: Seoul and Gyeonggi), region 2 (metropolitan cities: Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan), and region 3 (Sejong, Gangwon, Chungbuk, Chungnam, Jeollabuk, Jeollanam, Gyeongbuk, Gyeongnam, and Jeju). The presence or absence of disability was determined based on medical insurance disability codes.

Socioeconomic status: insurance quintile, which reflects income level. Income quintiles were categorized into medical benefits and the 1st to 4th quintiles, based on household insurance premiums divided into five groups representing 20 percentile increments in economic status. Insurance eligibility categories included region, workplace, and medical benefits.

Clinical severity and history: the Charlson Comorbidity Index (CCI) was used to measure the overall disease severity and presence of specific underlying diseases. The CCI serves as a measure of disease severity; it assigns specific weights to 19 specified conditions and the sum of these weights produces a total score [5]. CCI scores, calculated from health insurance claims data, were grouped into 1, 2, and 3 or more. The presence of comorbidities, including solid cancer, hematologic malignancy, organ transplantation, human immunodeficiency virus (HIV) infection, diabetes, alcohol dependence, and malnutrition, was assessed for six months preceding the diagnosis of infectious diseases by referencing the NHI diagnostic codes (Supplementary Table 1 in the online-only Data Supplement). Chemotherapy and steroid use were identified based on prescription codes for NHI-authorized therapeutic medications.

Healthcare setting denotes the category of medical institution where the patient was treated. Medical institutions were classified as senior general hospitals, general hospitals (more than 100 beds), hospitals (between 30 and 100 beds), clinics (fewer than 30 beds), nursing hospitals (long-term care facilities for elderly patients with underlying diseases, those requiring guardians, and those with cancer), and others. Senior general hospitals specifically deliver advanced medical care for severe diseases, as designated by the Ministry of Health and Welfare [6]. The 'others' category included dental hospitals, health centers, child health centers, and oriental medicine clinics. The initial medical institution was designated in case of patient transfer.

Condition-specific factors: Pregnancy status was considered for UTIs [7], while diagnoses such as necrotizing fasciitis, pyogenic arthritis, *Clostridium* muscle necrosis, and animal bites were assessed for STIs [8]. The presence or absence of diagnostic codes for pregnancy, necrotizing fasciitis, pyogenic arthritis, *Clostridium* muscle necrosis, and open wounds caused by bites was assessed within one month (Supplementary Table 1 in the online-only Data Supplement).

Bias

To minimize selection bias and misclassification, patients with more than two infectious diseases were excluded, and only the first infection episode for each patient during the study period was analyzed. Confounding factors were addressed using multivariate logistic regression analysis.

Study size

This study included all eligible patients with specified infectious diseases recorded in the NHI database between January 2020 and December 2022 to maximize the statistical power and generalizability.

Statistical methods

Multivariate analysis was performed to control for confounding variables and to identify the determinants influencing the prescription of microbial diagnostic tests. Logistic regression was used for statistical analysis, and significance was set at $P < 0.05$. All analyses were performed using the SAS software (version 9.4; SAS Institute). The NHI claims database contains minimal missing data on the core demographic and diagnostic variables. The analysis was performed on a complete-case basis, excluding a small number of records with missing data for any variables included in the model.

Results

Participants

During the study period, 8,803,283 patients were identified with a diagnosis code for infectious diseases. Of these, 222,703 were excluded because of complex or overlapping infections, and 311,588 were excluded because this was not their first recorded episode, resulting in a final analytical cohort of 8,268,992 patients.

Trends in requests for microbial diagnostic tests

The monthly number of TB-related tests, such as AFB smears, mycobacterium cultures, and molecular diagnostic tests (the number of tests displayed per million patients), showed a continuous increase, with a slight decline in April 2022 (Fig. 1).

Prescriptions were most frequent among patients with suspected pneumonia, with a peak monthly number of bacterial cultures and ASTs (per one million patients) in December 2021. However, the number of bacterial cultures and ASTs (per one million patients) consistently declined after June 2022, with the lowest

levels in December 2022 (Fig. 2A). The number of bacterial cultures and ASTs (per one million patients) peaked in 2022 and plateaued in patients with suspected sepsis (Fig. 2B). Among patients with suspected UTI, the numbers of bacterial cultures and ASTs (per one million patients) dropped sharply in 2022 and reached a plateau thereafter (Fig. 2C). The number of bacterial cultures and ASTs (per one million patients) showed a continuous decrease after 2022 in patients with suspected STI (Fig. 2D).

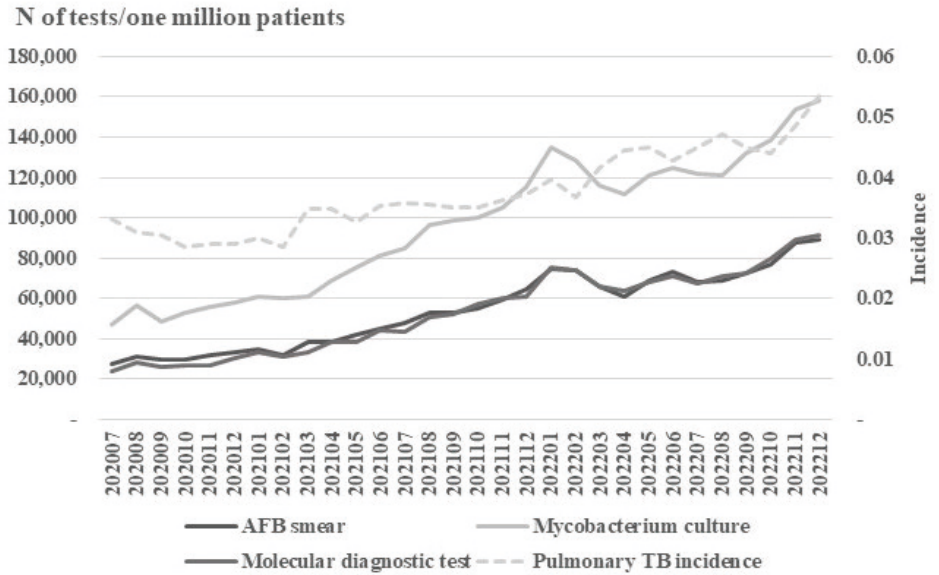


Fig. 1. Trends in requests for tuberculosis-related tests. N, number; AFB, acid-fast bacilli; TB, tuberculosis.

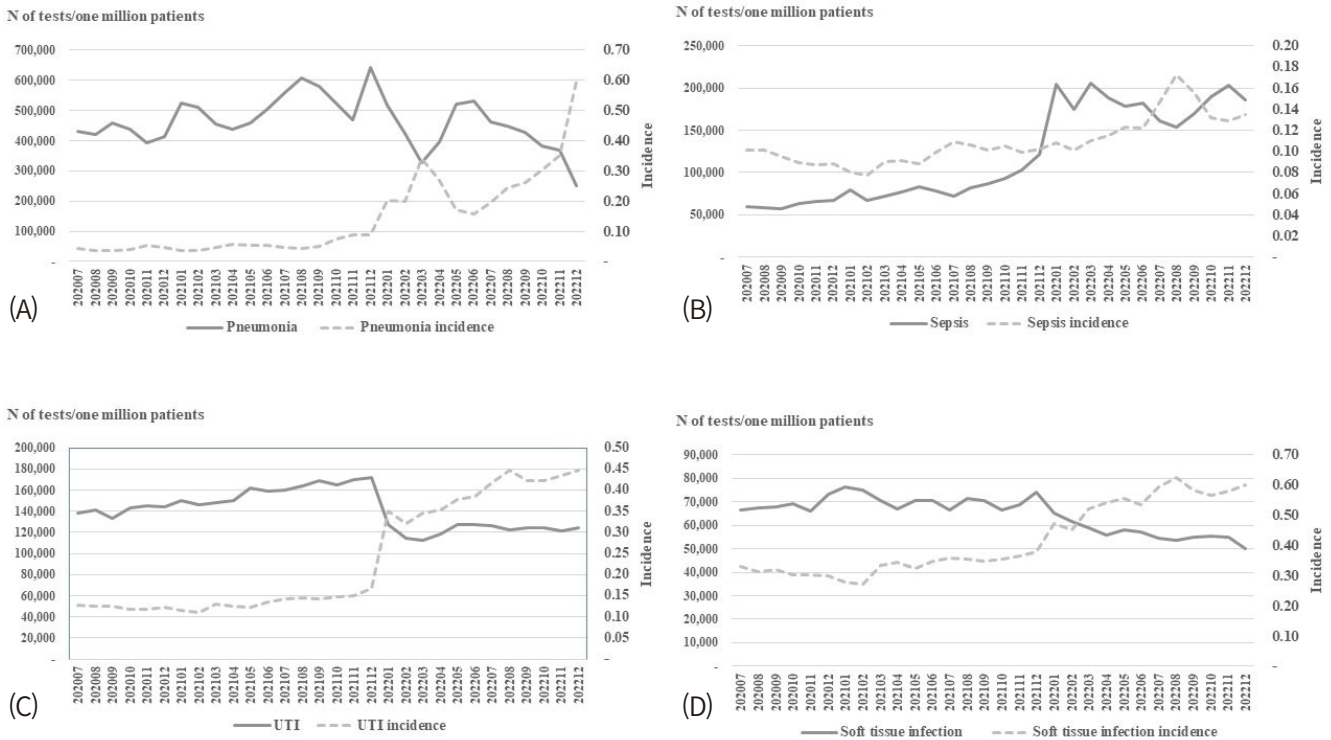


Fig. 2. Trends in requests for bacterial cultures and antimicrobial susceptibility tests for patients suspected of (A) pneumonia, (B) sepsis, (C) UTI, (D) soft tissue infection. N, number; UTI, urinary tract infection.

Factors associated with increased requests for TB-related tests

TB-related tests (AFB smear, mycobacterium culture, and molecular diagnostic tests) were more frequently requested among males, older adults (30-39 years and over 60 years), those with medical benefits, residents outside metropolitan areas, individuals without disabilities, patients with a CCI score greater than 2, nursing hospital admissions, patients receiving chemotherapy for solid cancer, those with hematologic malignancy, organ transplant recipients, individuals with alcohol dependency, and those with malnutrition (Table 1). However, HIV infection and diabetes were associated with fewer requests for TB-related testing.

Factors associated with increased requests for bacterial infection-related tests in pneumonia

Male sex, advanced age (> 80 years), receiving medical benefits, living in metropolitan areas, having a disability, a CCI score greater than 1, admission to senior general hospitals, receiving chemotherapy for solid cancer, hematologic malignancy, organ transplantation, alcohol dependency, malnutrition, and steroid use were all significant factors. Conversely, patients with diabetes or an HIV infection were less likely to undergo these tests (Table 2).

Factors associated with increased requests for bacterial infection-related tests in sepsis

Significant factors included male sex, younger age (< 19 years), receiving medical benefits, living outside metropolitan areas, presence of disability, CCI score > 2, senior general hospital admission, chemotherapy for solid cancer, hematologic malignancy, organ transplantation, alcohol dependency, and malnutrition. However, there were fewer requests from patients with HIV infection, diabetes, or steroid use (Table 2).

Factors associated with increased requests for bacterial infection-related tests in UTI

Significant factors included female sex, younger age (< 19 years), receipt of medical benefits, residence outside metropolitan cities or areas, disability, CCI greater than 1, admission to senior general hospitals, hematologic malignancy, organ transplantation, alcohol dependency, malnutrition, and steroid use. Conversely, lower request rates were observed among the groups undergoing chemotherapy for solid cancers and among those with HIV infection, diabetes, and pregnancy (Table 2).

Factors contributing to increased requests for bacterial infection-related tests in STI

Significant factors included male sex, older age (> 70 years), receipt of medical benefits, residence outside metropolitan cities or areas, disability, CCI greater than 1, admission to nursing hospitals, chemotherapy for solid cancer, hematological malignancy, organ transplantation, diabetes, alcohol dependency, malnutrition, steroid use, necrotizing fasciitis, pyogenic arthritis, *Clostridium* muscle necrosis, and open wounds. By contrast, requests were lower among individuals infected with HIV (Table 2).

Table 1. Factors affecting requests for tuberculosis-related tests: multivariate analysis

Characteristics	Variables	Total (n)	Incidence rate (%)	AFB smear			Mycobacterium culture			Molecular diagnostic test		
				OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Sex	Male	260,824	1.01	1	-	-	1	-	-	1	-	-
	Female	421,374	1.64	0.535	0.518 - 0.553	<0.0001	0.533	0.516 - 0.550	<0.0001	0.522	0.505 - 0.540	<0.0001
Age (yr)	≤ 19	42,344	0.52	1	-	-	1	-	-	1	-	-
	20-29	41,066	0.62	2.733	2.322 - 3.217	0.1562	2.637	2.245 - 3.098	0.2753	2.746	2.317 - 3.254	0.2527
	30-39	53,493	0.77	2.526	2.157 - 2.957	<0.0001	2.448	2.095 - 2.860	0.0005	2.715	2.305 - 3.197	0.0930
	40-49	69,234	0.85	2.772	2.379 - 3.230	0.1429	2.647	2.276 - 3.078	0.1679	2.862	2.441 - 3.356	0.8762
	50-59	110,809	1.29	3.007	2.591 - 3.491	0.0692	2.844	2.455 - 3.294	0.1385	3.008	2.576 - 3.514	0.0527
	60-69	152,864	2.11	3.092	2.667 - 3.585	0.0007	2.899	2.505 - 3.354	0.0099	2.925	2.507 - 3.414	0.4200
	70-79	134,527	3.73	3.698	3.187 - 4.291	<0.0001	3.411	2.946 - 3.949	<0.0001	3.484	2.984 - 4.069	<0.0001
≥ 80	77,861	3.79	7.338	6.324 - 8.515	<0.0001	6.819	5.888 - 7.897	<0.0001	7.139	6.113 - 8.336	<0.0001	
Insurance quintile	Medical benefits	51,784	3.40	1	-	-	1	-	-	1	-	-
	1st	140,810	1.39	0.958	0.901 - 1.018	0.0468	0.978	0.918 - 1.040	0.0268	0.982	0.920 - 1.048	0.0201
	2nd	120,629	1.15	0.989	0.928 - 1.053	0.0002	1.009	0.946 - 1.075	<0.0001	0.995	0.931 - 1.064	0.0034
	3rd	148,033	1.17	0.925	0.870 - 0.983	0.8406	0.943	0.886 - 1.004	0.9962	0.960	0.900 - 1.024	0.3086
Residential area	Region 3	240,611	1.49	1	-	-	1	-	-	1	-	-
	Region 2	156,328	1.21	0.848	0.814 - 0.884	0.0055	0.842	0.808 - 0.879	0.0001	0.888	0.851 - 0.928	0.4749
	Region 1	285,259	1.20	0.800	0.772 - 0.829	<0.0001	0.824	0.795 - 0.854	<0.0001	0.812	0.782 - 0.843	<0.0001
Disability	No			1	-	-	1	-	-	1	-	-
	Yes			0.899	0.862 - 0.937	<0.0001	0.904	0.866 - 0.944	<0.0001	0.904	0.865 - 0.945	<0.0001
Disease severity (CCI)	0			1	-	-	1	-	-	1	-	-
	1			1.205	1.137 - 1.278	0.9317	1.188	1.120 - 1.260	0.7244	1.164	1.095 - 1.238	0.1777
	2			1.289	1.212 - 1.372	<0.0001	1.278	1.200 - 1.360	0.0001	1.278	1.198 - 1.364	0.0001
	≥ 3			1.350	1.274 - 1.432	<0.0001	1.344	1.267 - 1.425	<0.0001	1.358	1.278 - 1.443	<0.0001
Types of medical institutions	Senior general hospitals			1	-	-	1	-	-	1	-	-
	General hospitals			0.779	0.753 - 0.806	<0.0001	0.778	0.752 - 0.806	<0.0001	0.848	0.819 - 0.879	<0.0001
	Hospitals			0.385	0.362 - 0.411	<0.0001	0.352	0.329 - 0.376	<0.0001	0.269	0.249 - 0.290	0.0893
	Clinics			0.014	0.012 - 0.015	<0.0001	0.013	0.012 - 0.014	<0.0001	0.013	0.012 - 0.014	<0.0001
	Nursing hospital			1.543	1.396 - 1.705	<0.0001	1.296	1.167 - 1.440	<0.0001	1.153	1.030 - 1.291	<0.0001
Others ^{a)}			0.084	0.054 - 0.129	<0.0001	0.069	0.043 - 0.112	<0.0001	0.063	0.037 - 0.107	<0.0001	
Chemotherapy in solid cancer	No			1	-	-	1	-	-	1	-	-
	Yes			1.075	1.016 - 1.136	0.0114	1.080	1.021 - 1.143	0.0069	1.027	0.967 - 1.089	0.3854
Hematologic malignancy	No			1	-	-	1	-	-	1	-	-
	Yes			1.125	1.016 - 1.244	0.0233	1.149	1.038 - 1.271	0.0073	1.141	1.026 - 1.268	0.0150
Organ transplantation	No			1	-	-	1	-	-	1	-	-
	Yes			1.269	1.082 - 1.490	0.0035	1.324	1.131 - 1.551	0.0005	1.149	0.967 - 1.367	0.1151
HIV infection	No			1	-	-	1	-	-	1	-	-
	Yes			0.756	0.606 - 0.943	0.0133	0.791	0.637 - 0.984	0.0349	0.717	0.569 - 0.903	0.0047
Diabetes	No			1	-	-	1	-	-	1	-	-
	Yes			0.351	0.338 - 0.364	<0.0001	0.350	0.337 - 0.363	<0.0001	0.338	0.326 - 0.352	<0.0001
Alcohol dependence	No			1	-	-	1	-	-	1	-	-
	Yes			1.735	1.542 - 1.952	<0.0001	1.738	1.543 - 1.957	<0.0001	1.671	1.475 - 1.892	<0.0001
Malnutrition	No			1	-	-	1	-	-	1	-	-
	Yes			1.883	1.764 - 2.010	<0.0001	1.845	1.726 - 1.972	<0.0001	1.707	1.590 - 1.832	<0.0001
Steroid treatment	No			1	-	-	1	-	-	1	-	-
	Yes			1.001	0.969 - 1.033	0.9636	0.996	0.964 - 1.029	0.8034	1.014	0.980 - 1.048	0.4228

Bold form: statistically significant.

^{a)}Others included dental hospitals, healthcare centers, child health centers, and oriental medicine clinics.

Abbreviations: AFB, acid-fast bacilli; OR, odds ratio; CI, confidence interval; CCI, Charlson Comorbidity Index; HIV, human immunodeficiency virus.

Table 2. Factors affecting bacterial culture and antimicrobial susceptibility tests: multivariate analysis

Characteristics	Pneumonia						Sepsis						Urinary tract infection						Soft tissue infection						
	Total (n)	Incidence rate (%)	OR	95% CI	P	Total (n)	Incidence rate (%)	OR	95% CI	P	Total (n)	Incidence rate (%)	OR	95% CI	P	Total (n)	Incidence rate (%)	OR	95% CI	P	Total (n)	Incidence rate (%)	OR	95% CI	P
Sex	1,158,288	4.50	1	-	-	787,410	3.06	1	-	-	1,181,580	4.59	1	-	-	2,965,689	11.52	1	-	-	2,965,689	11.52	1	-	-
Female	1,331,530	5.19	0.789	0.782-0.796	<0.0001	1,177,562	4.59	0.856	0.840-0.872	<0.0001	2,827,982	11.02	1.440	1.426-1.455	<0.0001	4,439,665	17.29	0.781	0.773-0.789	<0.0001	4,439,665	17.29	0.781	0.773-0.789	<0.0001
Age (yr)																									
≤ 19	878,496	10.77	1	-	-	369,517	4.53	1	-	-	363,021	4.45	1	-	-	1,034,285	12.68	1	-	-	1,034,285	12.68	1	-	-
20-29	154,422	2.33	0.245	0.237-0.254	<0.0001	218,816	3.30	0.148	0.139-0.158	<0.0001	345,349	5.21	0.269	0.263-0.276	<0.0001	813,367	12.28	0.775	0.747-0.804	<0.0001	813,367	12.28	0.775	0.747-0.804	<0.0001
30-39	196,214	2.83	0.275	0.267-0.283	<0.0001	225,691	3.26	0.154	0.146-0.163	<0.0001	433,155	6.26	0.218	0.213-0.224	<0.0001	885,662	12.79	0.729	0.705-0.754	<0.0001	885,662	12.79	0.729	0.705-0.754	<0.0001
40-49	216,575	2.65	0.306	0.299-0.314	<0.0001	233,956	2.86	0.193	0.184-0.203	<0.0001	522,278	6.39	0.237	0.232-0.242	<0.0001	972,174	11.89	0.732	0.710-0.755	<0.0001	972,174	11.89	0.732	0.710-0.755	<0.0001
50-59	232,689	2.70	0.351	0.344-0.358	<0.0001	279,990	3.25	0.220	0.211-0.229	<0.0001	698,113	8.10	0.265	0.260-0.270	<0.0001	1,175,666	13.64	0.785	0.762-0.807	<0.0001	1,175,666	13.64	0.785	0.762-0.807	<0.0001
60-69	307,508	4.24	0.415	0.407-0.422	<0.0001	298,548	4.12	0.283	0.273-0.294	<0.0001	762,451	10.52	0.296	0.291-0.302	<0.0001	1,219,787	16.83	0.949	0.923-0.976	0.6523	1,219,787	16.83	0.949	0.923-0.976	0.6523
70-79	256,790	7.11	0.615	0.604-0.626	<0.0001	202,898	5.62	0.408	0.393-0.424	<0.0001	529,278	14.66	0.410	0.402-0.418	<0.0001	808,478	22.40	1.310	1.273-1.347	<0.0001	808,478	22.40	1.310	1.273-1.347	<0.0001
≥ 80	247,124	12.03	1.218	1.197-1.239	<0.0001	135,556	6.60	0.586	0.565-0.609	<0.0001	355,917	17.33	0.821	0.806-0.836	<0.0001	495,935	24.15	1.672	1.625-1.721	<0.0001	495,935	24.15	1.672	1.625-1.721	<0.0001
Insurance quintile																									
Medical benefits	117,885	7.74	1	-	-	95,896	6.30	1	-	-	189,335	12.44	1	-	-	317,294	20.84	1	-	-	317,294	20.84	1	-	-
1st	500,468	4.95	0.824	0.808-0.839	0.0011	407,336	4.03	0.924	0.892-0.958	0.4517	874,066	8.65	0.769	0.754-0.784	<0.0001	1,566,003	15.50	0.765	0.750-0.780	<0.0001	1,566,003	15.50	0.765	0.750-0.780	<0.0001
2nd	404,582	3.87	0.845	0.829-0.861	0.0337	362,397	3.47	0.937	0.903-0.973	0.0406	742,253	7.11	0.782	0.767-0.798	0.4451	1,398,004	13.38	0.800	0.784-0.816	0.6651	1,398,004	13.38	0.800	0.784-0.816	0.6651
3rd	624,273	4.94	0.826	0.811-0.841	0.0039	460,570	3.65	0.923	0.890-0.956	0.5587	915,774	7.25	0.760	0.745-0.775	<0.0001	1,737,600	13.76	0.765	0.750-0.780	<0.0001	1,737,600	13.76	0.765	0.750-0.780	<0.0001
4th	842,610	5.01	0.710	0.698-0.723	<0.0001	638,773	3.80	0.814	0.787-0.842	<0.0001	1,288,134	7.66	0.653	0.641-0.665	<0.0001	2,386,453	14.20	0.692	0.679-0.704	<0.0001	2,386,453	14.20	0.692	0.679-0.704	<0.0001
Residential area																									
Region 3	880,301	5.44	1	-	-	621,568	3.84	1	-	-	1,300,319	8.04	1	-	-	2,367,804	14.64	1	-	-	2,367,804	14.64	1	-	-
Region 2	606,751	4.71	0.958	0.947-0.968	<0.0001	469,702	3.64	0.885	0.863-0.906	<0.0001	993,619	7.71	0.925	0.914-0.936	0.0485	1,770,905	13.73	0.989	0.976-1.003	<0.0001	1,770,905	13.73	0.989	0.976-1.003	<0.0001
Region 1	1,002,766	4.20	1.020	1.010-1.030	<0.0001	873,702	3.66	0.963	0.943-0.983	0.0166	1,715,624	7.19	0.837	0.828-0.846	<0.0001	3,266,645	13.69	0.909	0.898-0.919	<0.0001	3,266,645	13.69	0.909	0.898-0.919	<0.0001
Disability																									
No			1	-	-			1	-	-			1	-	-			1	-	-			1	-	-
Yes			1.509	1.490-1.528	<0.0001			1.387	1.354-1.421	<0.0001			1.470	1.450-1.490	<0.0001			1.685	1.663-1.706	<0.0001			1.685	1.663-1.706	<0.0001
Disease severity (CCI)			1	-	-			1	-	-			1	-	-			1	-	-			1	-	-
0			1.461	1.442-1.48	<0.0001			0.992	0.963-1.023	<0.0001			1.036	1.022-1.050	<0.0001			1.402	1.372-1.433	<0.0001			1.402	1.372-1.433	<0.0001
1			1.546	1.519-1.574	<0.0001			1.320	1.272-1.371	<0.0001			1.154	1.135-1.174	<0.0001			1.759	1.718-1.801	<0.0001			1.759	1.718-1.801	<0.0001
2			1.855	1.823-1.887	<0.0001			1.772	1.712-1.834	<0.0001			1.340	1.319-1.362	<0.0001			3.340	3.267-3.415	<0.0001			3.340	3.267-3.415	<0.0001
≥ 3			1	-	-			1	-	-			1	-	-			1	-	-			1	-	-
Type of medical institutions																									
Senior general hospitals			0.835	0.824-0.846	<0.0001			0.377	0.368-0.386	<0.0001			0.912	0.900-0.924	<0.0001			0.628	0.618-0.638	<0.0001			0.628	0.618-0.638	<0.0001
General hospitals			0.462	0.455-0.469	<0.0001			0.077	0.074-0.080	<0.0001			0.481	0.473-0.489	<0.0001			0.513	0.502-0.523	<0.0001			0.513	0.502-0.523	<0.0001
Hospitals			0.065	0.064-0.066	<0.0001			0.010	0.010-0.011	<0.0001			0.080	0.079-0.082	<0.0001			0.197	0.195-0.200	<0.0001			0.197	0.195-0.200	<0.0001
Clinics			0.700	0.685-0.715	<0.0001			0.784	0.761-0.808	<0.0001			0.727	0.704-0.751	<0.0001			1.243	1.210-1.277	<0.0001			1.243	1.210-1.277	<0.0001
Nursing hospital			0.137	0.117-0.161	<0.0001			0.023	0.017-0.031	<0.0001			0.136	0.122-0.152	<0.0001			0.351	0.324-0.380	<0.0001			0.351	0.324-0.380	<0.0001
Others ^{b)}			1	-	-			1	-	-			1	-	-			1	-	-			1	-	-
Chemotherapy in solid cancer			1.358	1.328-1.389	<0.0001			1.751	1.686-1.819	<0.0001			0.955	0.931-0.979	0.0003			1.898	1.858-1.940	<0.0001			1.898	1.858-1.940	<0.0001

Table 2. Factors affecting bacterial culture and antimicrobial susceptibility tests: multivariate analysis (continued)

Characteristics	Variates	Pneumonia					Sepsis					Urinary tract infection					Soft tissue infection					
		Total (n)	Incidence rate (%)	OR	95% CI	P	Total (n)	Incidence rate (%)	OR	95% CI	P	Total (n)	Incidence rate (%)	OR	95% CI	P	Total (n)	Incidence rate (%)	OR	95% CI	P	
Hematologic malignancy	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	1782	1.711-1.856	1.839	1.730-1.954	<0.0001	1.839	1.730-1.954	1.839	1.730-1.954	<0.0001	1.182	1.118-1.250	1.182	1.118-1.250	<0.0001	1.887	1.809-1.968	1.887	1.809-1.968	<0.0001	
Organ transplantation	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	1585	1.504-1.670	1.396	1.283-1.518	<0.0001	1.396	1.283-1.518	1.664	1.575-1.758	<0.0001	1.664	1.575-1.758	1.664	1.575-1.758	<0.0001	2.029	1.940-2.122	2.029	1.940-2.122	<0.0001	
HIV infection	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	0.855	0.747-0.980	0.536	0.418-0.688	<0.0001	0.536	0.418-0.688	0.515	0.432-0.615	<0.0001	0.515	0.432-0.615	0.515	0.432-0.615	<0.0001	0.833	0.723-0.960	0.833	0.723-0.960	0.0117	
Diabetes	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	0.899	0.889-0.909	0.909	0.889-0.930	<0.0001	0.909	0.889-0.930	0.942	0.932-0.953	<0.0001	0.942	0.932-0.953	0.942	0.932-0.953	<0.0001	2.613	2.573-2.654	2.613	2.573-2.654	<0.0001	
Alcohol dependence	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	2.088	2.001-2.179	1.692	1.562-1.832	<0.0001	1.692	1.562-1.832	1.845	1.759-1.935	<0.0001	1.845	1.759-1.935	1.845	1.759-1.935	<0.0001	1.712	1.642-1.785	1.712	1.642-1.785	<0.0001	
Malnutrition	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	1.927	1.883-1.971	1.828	1.754-1.906	<0.0001	1.828	1.754-1.906	1.698	1.651-1.746	<0.0001	1.698	1.651-1.746	1.698	1.651-1.746	<0.0001	1.765	1.717-1.815	1.765	1.717-1.815	<0.0001	
Steroid treatment	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	1.227	1.216-1.237	0.911	0.894-0.928	<0.0001	0.911	0.894-0.928	1.093	1.083-1.104	<0.0001	1.093	1.083-1.104	1.093	1.083-1.104	<0.0001	1.141	1.130-1.153	1.141	1.130-1.153	<0.0001	
Pregnancy	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	0.712	0.685-0.740	0.712	0.685-0.740	<0.0001	0.712	0.685-0.740	0.712	0.685-0.740	<0.0001	0.712	0.685-0.740	0.712	0.685-0.740	<0.0001	1.199	1.182-1.216	1.199	1.182-1.216	<0.0001	
Necrotizing fasciitis	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	13.21	11.912-14.649	13.21	11.912-14.649	<0.0001	13.21	11.912-14.649	13.21	11.912-14.649	<0.0001	13.21	11.912-14.649	13.21	11.912-14.649	<0.0001	13.21	11.912-14.649	13.21	11.912-14.649	<0.0001	
Pyogenic arthritis	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	3.21	3.097-3.328	3.21	3.097-3.328	<0.0001	3.21	3.097-3.328	3.21	3.097-3.328	<0.0001	3.21	3.097-3.328	3.21	3.097-3.328	<0.0001	3.21	3.097-3.328	3.21	3.097-3.328	<0.0001	
Clostridium muscle necrosis	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	9.751	6.077-15.647	9.751	6.077-15.647	<0.0001	9.751	6.077-15.647	9.751	6.077-15.647	<0.0001	9.751	6.077-15.647	9.751	6.077-15.647	<0.0001	9.751	6.077-15.647	9.751	6.077-15.647	<0.0001	
Open wounds by bites	No	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	1	-	1	-	-	-
	Yes	1.199	1.182-1.216	1.199	1.182-1.216	<0.0001	1.199	1.182-1.216	1.199	1.182-1.216	<0.0001	1.199	1.182-1.216	1.199	1.182-1.216	<0.0001	1.199	1.182-1.216	1.199	1.182-1.216	<0.0001	

Bold form: statistically significant.

^aOthers included dental hospitals, healthcare centers, child health centers, and oriental medicine clinics.

Abbreviations: OR, odds ratio; CI, confidence interval; CCI, Charlson comorbidity index; HIV, human immunodeficiency virus.

Discussion

Key results

Requests for TB-related tests consistently increased, whereas those for bacterial tests varied by infection type and peaked for pneumonia. Test ordering was higher in patients with risk factors such as male sex, older age, high disease severity (CCI > 2), and comorbidities such as cancer and malnutrition. Conversely, HIV infection and diabetes were generally associated with fewer requests across most types of infection.

Interpretation/comparison with previous studies

Active microbiological diagnostic tests are required for patients at a higher risk of infection. The known risk factors for pulmonary TB include undernourishment, smoking, alcohol use, diabetes, and HIV [9]. Various risk factors have been identified for bacterial infections. Age, smoking, environmental exposure, malnutrition, previous community-acquired pneumonia (CAP), chronic bronchitis/chronic obstructive pulmonary disease, asthma, functional impairment, poor dental health, immunosuppressive therapy, oral steroids, and treatment with gastric acid-suppressive drugs were definitive risk factors for CAP [10]. Several well-known risk factors for sepsis include multiple comorbidities, polypharmacy, immunosuppression, and indwelling devices [11]. Women are more prone to UTIs because of behavioral factors, susceptibility factors, genetic factors, age-specific factors, pregnancy-related factors, and urinary catheterization [12]. However, there have been no studies on the risk factors for infections, including socioeconomic aspects such as types of medical institutions, residential area, insurance quintile, and disability, in addition to clinical factors. This study aimed to assess the factors influencing requests for microbial diagnostic tests in patients with various infections, which could serve as baseline data for the management of adequate microbiological tests in Korea.

TB-related tests were more frequent in males in this study, although the incidence of female patients was higher. The prevalence of TB is significantly higher among men, and there is strong evidence that men are disadvantaged in seeking and/or accessing TB care in many settings [13]. This finding is inconsistent with that of a previous study and requires further investigation into the affecting factors. In this study, more bacterial infection-related tests were performed on females. Sex differences in bacterial infections have been reported due to differences in immunity, health-seeking behaviors, quality of health care, and adherence to treatment recommendations [14].

In this study, TB-related tests were more frequently requested among patients over 60 years of age, and the incidence rates increased, which is consistent with the high prevalence of pulmonary TB in older patients in Korea [15]. However, it was unexpected that requests for TB-related tests were high in the 30-39 age group, which requires further investigation. Bacterial infection tests were more frequently requested among patients aged > 80 years, and the incidence rate increased rapidly in this group. Elderly individuals are vulnerable to infections because of their increased stay in hospitals (or long-term care facilities) and exposure to drug-resistant pathogens [16]. An aging immune system is also associated with bacterial infections [16].

According to the insurance quintile, the group with medical benefits received more TB-related test orders, which is consistent with the finding of a higher TB incidence in this group with medical benefits [15]. In

a cross-country regression study, income inequality may create conditions under which TB spreads more easily [17]. The group with medical benefits received more bacterial infection-related test orders and had the highest incidence rate. Poverty increases the risk of contracting infectious diseases, but evidence regarding this relationship is lacking compared to that for TB cases [18].

Disabled patients underwent fewer TB-related tests, emphasizing the need to enhance accessibility to people with disabilities. Patients with a CCI score greater than 2 requested more TB-related tests and were more likely to have nursing hospital admissions, which is likely reflective of an environment where group living increases susceptibility to infections. Bacterial infection-related tests were more frequently performed in general hospitals, possibly because of greater disease severity.

This study demonstrated that clinicians are more likely to prescribe microbiological diagnostic tests to patients with various underlying diseases, such as solid cancer, hematologic malignancy, organ transplantation, alcohol dependence, and malnutrition. Diabetic patients suspected of having STI were requested to undergo bacterial infection-related tests, but those with other types of infection were not. Compared with control subjects without diabetes, patients with diabetes had higher rates of all infections, with the highest incidence rate observed for bone and joint infections, sepsis, and cellulitis [19]. Therefore, a more active workup for sepsis is needed in patients with diabetes. Patients with HIV infection showed fewer requests for diagnostic tests, but this should be interpreted with caution, as the sample size was smaller than that for other comorbidities.

Limitations

Data inaccuracy may arise because such datasets reflect physician billing activities rather than the actual clinical status of patients. Individuals with different types of medical benefits and variations across residential regions remain unclear and require further investigation. Nevertheless, this study analyzed rare large-scale national data on various factors affecting test prescriptions, which could help select a target group that needs to focus on policies for appropriate test prescriptions.

Suggestion for further studies

More studies are needed to explain why lower request rates were observed in pregnant women, because pregnancy is a well-known risk factor for UTI [12]. According to Korean guidelines for UTI management [7], urine culture is not mandatory; however, it is recommended for pregnant women. Considering the increased rate of antibiotic resistance among UTI pathogens in Korea [20], more active urine culture testing is needed, especially in pregnant patients.

Patients diagnosed with necrotizing fasciitis, pyogenic arthritis, *Clostridium* muscle necrosis, and open wounds were requested to undergo additional microbiological tests, as recommended in the Korean guidelines for STI management [8]. In this study, more tests were requested in patients receiving chemotherapy for solid cancer, hematologic malignancy, organ transplantation, diabetes, alcohol dependency, malnutrition, and steroid use, which is consistent with the guidelines recommending tests for immunocompromised individuals [21].

Generalizability

This study utilized a comprehensive nationwide database: therefore, the findings are highly generalizable to the entire insured population of South Korea. However, caution should be exercised when extrapolating these results to countries with significantly different healthcare, insurance, and reimbursement systems.

Conclusion

This study analyzed rare large-scale national data on various factors affecting test prescriptions, which could provide useful data for improving policies for appropriate test prescriptions.

Supplementary materials

The following supplementary materials are available on the journal's website:

- Supplementary Table 1. Diagnosis code of Korean Standard Classification of Diseases
- Supplementary Table 2. Korean National Health Insurance codes of microbial diagnostic tests

Ethics statement

This study was approved by the Institutional Review Board of National Health Insurance Service Ilsan Hospital (approval number: NHIMC IRB 2024-10-023).

Conflicts of interest

No potential conflicts of interest relevant to this article were reported.

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Data availability

This study used NHIS-NSC data (NHIS-2025-05-08-1-039) from the National Health Insurance Service (NHIS).

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